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REPORT

OF THE

ADVISORY COMMITTEE FOR AERONAUTICS

FOR THE YEAR 1919-20.

Presented to Parliament by Command of His Majesty.

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MEMBERS OF THE COMMITTEE, MARCH, 1920.

Sir Richard Glazebrook, K.C.B., F.R.S. (*Chairman*).

Air Commodore H. R. M. Brooke-Popham, C.B., C.M.G., D.S.O., A.F.C.

Sir Horace Darwin, K.B.E., F.R.S.

Sir H. Tennyson d'Eyncourt, K.C.B.

Sir G. Greenhill, F.R.S.

Mr. F. W. Lanchester, M.Inst.C.E.

Mr. H. R. A. Mallock, F.R.S.

Lieut.-Colonel Mervyn O'Gorman, C.B.

Professor J. E. Petavel, F.R.S.

Sir Napier Shaw, F.R.S.

Secretary :—Mr. F. J. Selby;

Assistant Secretary :—Mr. J. L. Nayler,

National Physical Laboratory,
Teddington,
Middlesex.

Report for the Year 1919-20.

To the Right Honourable WINSTON CHURCHILL, M.P.,
Secretary of State for Air.

SIR,

1. The Advisory Committee for Aeronautics begs to submit its report for the year 1919–20.

2. At the two first meetings of the year, in April and May, 1919, the chair was occupied by the President, the late Lord Rayleigh. Lord Rayleigh was nominated President of the Committee on its appointment in April, 1909, by the then Prime Minister, Mr. Asquith, and during the ten years of his tenure of that position, except on rare occasions, when prevented from attending through illness or absence from the country, had continuously presided at its meetings. At the June meeting he was unable to be present owing to the illness which shortly afterwards proved fatal, and in their report for the year 1918–19, which was then passing through the press, the Committee were able to include a note giving the terms of the resolution in which they expressed their sense of the loss the country had sustained by his death. He had throughout taken the greatest interest in the work of the Committee and in the progress of aeronautical research, to the successful prosecution of which he had himself greatly contributed both as President of the Committee and by his own personal investigations. The Committee desire again to put on record their high appreciation of the invaluable services rendered to British science, and to aeronautics in particular, by their esteemed and honoured President.

3. Other changes have taken place in the *personnel* of the Committee since the date of the previous report. Sir Dugald Clerk resigned his membership and the chairmanship of the Internal Combustion Engine Sub-Committee at the end of March, 1919. Major-General Sir W. S. Brancker and Mr. E. C. Given retired during the course of the year under review. Air Commodore Brooke-Popham, Director of Research at the Air Ministry, now represents the Air Ministry on the Committee.

The names of the members of the various Sub-Committees are given below.*

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* The following are the names of the members of the Sub-Committees :—

Engine Sub-Committee.—Lieut.-Colonel Mervyn O'Gorman, C.B., Major E. S. Saunders, Dr. T. E. Stanton, F.R.S., representing the National Physical Laboratory; Commander T. B. Barrington, R.N.V.R., and Captain G. W. A. Brown, representing the Air Ministry; Brig.-General R. K. Bagnall Wild, C.M.G., and Major G. P. Bulman, representing the Aeronautical Inspection Directorate; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Light Alloys Sub-Committee.—Professor C. F. Jenkin (Chairman); W. H. Dyson, representing the Royal Aircraft Establishment; Professor F. C.

(B4551) Wt. 6528—120. 1000 & 90. 2/21. Sir J. C. & S. **Gp. 32.**

4. This report is the final report of the Committee as at present constituted. In February, 1920, the Chairman of the Committee received the following communication from the Air Council :—

Air Ministry,
Kingsway, W.C.2.

Ref. No. A.8440. *9th February*, 1920.

" Sir,

" I am commanded by the Air Council to state for the information of the Advisory Committee for Aeronautics that they have had under consideration and have submitted to His Majesty's Government the question of the future arrangements to be made for the control of aeronautical research.

Lea, representing the Air Ministry ; Captain H. P. Philpot, representing the Aeronautical Inspection Directorate ; Mr. A. W. Johns, Chief Constructor, representing the Director of Naval Construction ; Dr. W. Rosenhain, F.R.S., representing the National Physical Laboratory ; Professor C. A. Edwards with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Aerodynamics Sub-Committee.—Sir J. E. Petavel, K.B.E., F.R.S. (Chairman) ; Sir G. Greenhill, F.R.S ; Professor H. Lamb, F.R.S. ; Lieut.-Colonel Mervyn O'Gorman, C.B. ; Lieut.-Colonel J. H. Landon, D.S.O., of the Air Ministry ; Dr. T. E. Stanton, C.B.E., F.R.S., and Mr. E. F. Relf, A.R.C.Sc., of the National Physical Laboratory ; Captain W. S. Farren, C.B.E. ; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Meteorology Sub-Committee.—Sir Napier Shaw, F.R.S. (Chairman) ; Mr. G. M. B. Dobson ; Lieut.-Colonel Harries ; Mr. A. Mallock, F.R.S. ; Lieut.-Colonel Mervyn O'Gorman, C.B ; Sir J. E. Petavel, K.B.E., F.R.S. ; Dr. T. E. Stanton, C.B.E., F.R.S. ; Mr. G. I. Taylor, M.A. ; Mr. C. T. R. Wilson, F.R.S. ; Major H. E. Wimperis, R.A.F. ; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Special Committee on the Electrification of Balloons.—Sir Napier Shaw, F.R.S. (Chairman) ; Lieut.-Colonel Cave-Brown-Cave ; Captain C. J. P. Cave ; Mr. A. Mallock, F.R.S. ; Lieut.-Colonel Mervyn O'Gorman, C.B. ; Sir J. E. Petavel, K.B.E., F.R.S. ; Lieut. W. H. Rose, of the Air Ministry ; Mr. F. E. Smith, O.B.E., F.R.S., of the National Physical Laboratory ; Mr. C. T. R. Wilson, F.R.S. ; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Fire Prevention Sub-Committee.—Lieut.-Colonel Mervyn O'Gorman, C.B. (Chairman) ; Lieut.-Colonel Cave-Brown-Cave ; Mr. G. B. Cockburn, O.B.E. ; Wing Commander L. F. R. Fell, D.S.O., M.V.O., O.B.E. ; Sir J. E. Petavel, K.B.E., F.R.S. ; Dr. J. E. Ramsbottom ; with the Chairman of the Advisory Committee for Aeronautics (*ex officio*).

Load Factor Sub-Committee.—Sir Richard Glazebrook, K.C.B., F.R.S. (Chairman) ; Lieut.-Colonel W. D. Beatty, R.A.F., Squadron Leader F. H. Bramwell, R.A.F., representing the Air Council ; Mr. A. J. Sutton Pippard, M.B.E., M.Sc., A.M.I.C.E., Mr. L. Bairstow, C.B.E., F.R.S., representing the Royal Aeronautical Society ; Mr. F. Handley Page, Captain F. S. Barnwell, Mr. H. Smith, Mr. H. O. Short, representing the Society of British Aircraft Constructors ; Sir J. E. Petavel, K.B.E., F.R.S., Mr. F. W. Lanchester, M.Inst.C.E., Mr. R. V. Southwell, M.A., Dr. T. E. Stanton, C.B.E., F.R.S., representing the Advisory Committee for Aeronautics.

"As the Committee are no doubt aware, a Committee was appointed by the late Secretary of State for Air, under the chairmanship of Sir R. Glazebrook, to report on the whole question of aeronautical education and research after the war. The report of that Committee will shortly be laid before Parliament, and its recommendations have been approved by the Air Council.

"One of the recommendations is that the Advisory Committee on Aeronautics should be replaced by an Aeronautical Research Committee, with appropriate Sub-Committees, and with functions differing from those of the present Committee. The necessary steps are being taken for the formation of the new Committee, but some little time may be expected to elapse before it can function.

"The Air Council think, however, that it is proper to inform the Advisory Committee of the situation at the earliest possible moment, and I am to request that you will cause this letter to be communicated to them at their next meeting, with a request that they will continue their service to the State until the new Committee can be formally constituted.

"The Air Council would desire to take this opportunity of expressing their deep sense of appreciation of the magnificent services rendered to the cause of aviation by the Committee since its establishment and especially during the years of war. The Council feel that without the assistance of the Committee the progress which has put British aviation at the front of the world would have been impossible, and they desire me to convey to you and to every member of the Committee the most cordial message of appreciation and gratitude.

"I am, Sir,

"Your obedient Servant,

(Signed) "W. A. Robinson."

The work of the present Committee will be continued by the new Aeronautical Research Committee, with somewhat wider functions and extended powers. The Advisory Committee have no doubt that the future of aeronautical research will be well and wisely cared for by the Aeronautical Research Committee, under the chairmanship of Sir Richard Glazebrook, who has held the position of chairman of the Advisory Committee since its formation. They desire once again to emphasize the immense importance of research in aeronautics. The value of the work done in this country prior to 1914 was amply demonstrated during the war. It enabled the development and design of new types of aircraft to be accomplished rapidly and with accurate knowledge, with the minimum of loss from defects due to lack of data and need of special investigation for which much time is necessary, which is not available in a national emergency. The best hope for the future of aeronautics, whether in its uses for commercial and civil purposes or for defence, lies in the continued development and extension of research. There is a wide field to be explored—as yet we have scarcely advanced beyond the border line—and no one can say what possibilities lie hidden in the unknown country beyond. But already we can see far enough to be assured that its exploration is of immense importance for the civilisation of the future and that no effort should be spared in carrying forward the work. At the moment the chief need would appear to be the improvement of the methods of propulsion, especially as regards the reliability and endurance of the engine. Much pioneering work is, however, still required in the development of the large aeroplane and of the airship.

5. *Equipment for Experimental Work at the National Physical Laboratory and at the Royal Aircraft Establishment.*—The two chief centres for aeronautical research in this country are at present the National Physical Laboratory and the Royal Aircraft Establishment. The National Physical Laboratory is equipped for experiments on models and for such other work as can suitably be carried out in a central research laboratory. The Royal Aircraft Establishment has devoted attention mainly to full-scale work on aeroplanes, engines, propellers, &c., in earlier days also on airships, but such work as is at present done in this direction is now carried out elsewhere (see below, § 6). During the war, however, the wind channel equipment at the R.A.E. was improved and extended, so that it is now able to carry out much of the model work required in connection with its full-scale experiments, and also to contribute to model research. The two institutions working in co-operation constitute a well-equipped centre for carrying out research in aeronautics, apart from the full-scale work required on seaplanes and on airships. The wind channels available at the N.P.L. comprise three 7 ft., two 4 ft., and one 3 ft. As stated in the previous report, a channel 14 ft. × 7 ft. in section is under construction; progress with this has unfortunately been slow under the conditions which have existed during the past year, and it is not yet quite completed, though it will probably be in use before the date of issue of the present report. In addition the Laboratory is provided with a whirling arm, used earlier for tests of propeller models, for which, however, wind channel methods are now found in general more convenient; the whirling arm is valuable for special tests required from time to time. There are also two wind towers, on which experiments can be made in a natural wind. Tests on models of seaplane floats and flying boats are carried out in the William Froude Tank. Tests are also made in the tank on models immersed in water, while tests of anemometers and other investigations can be made at moderate speeds on the tank carriage.

Other departments of the N.P.L. provide facilities for subsidiary classes of investigation. In the Engineering Department provision has been made for experiments on engines, though the greater part of this work is done at the R.A.E. Attention has been given especially to the problem of engine cooling, more particularly in the direction of determining the fundamental laws governing the transmission of heat from surfaces to fluids flowing over them; with this is also closely associated the research relating to the friction of fluids. The Engineering Department is also equipped for experiments on the strength of materials and of aeroplane parts, especially under repeated stress, impact, &c., at normal and at high temperatures; this work is of particular importance in aeronautical design. The Metallurgy Department affords full facilities for the study of alloys suitable for aircraft construction. With its furnace and foundry equipment, rolling mill, &c., it is provided with the means necessary for investigating the difficulties attending the production on a manufacturing scale of such alloys as are found to have valuable properties for constructional purposes. In the Chemistry Department equipment is available for the study of fabrics, proofings and dopes, and for other chemical work, such as the investigation of methods of examining the purity of hydrogen, the use of helium for airships and similar problems. In the Electrical, Heat and other Departments of the Laboratory special problems are investigated; much attention has been given, for example, to magneto research.

At the R.A.E. attention is directed to full-scale research on aeroplanes (both aerodynamically and for structural strength) engines and propellers. Much work is also done on the development of navigational and other instruments and auxiliary apparatus for use in aircraft, and research is conducted on the special dopes and varnishes required for wings, &c. There is also a metallurgical laboratory for investigation of materials. As is well known, the full-scale investigations carried out on aeroplanes at the R.A.E. have been of the highest value, demanding exceptional skill and audacity on the part of the flying officers and observers, and great experimental ability. All the main aerodynamical properties of the aeroplane, including stability, have been investigated on machines in flight; and the behaviour of engines and propellers has also been closely studied. The equipment of the R.A.E. includes two 7-ft. wind channels and one 4-ft., a complete installation capable of carrying out tests on aircraft engines of all sizes up to 1,200 h.p., including provision for tests under high altitude conditions, with variation of air pressure and temperature, for engines up to 250 h.p.; a whirling arm for full-scale propeller tests; foundry and factory facilities for the production of experimental aeroplanes and engines, and well-equipped chemical, metallurgical, physical and engineering laboratories for the study of special problems. Attention was especially devoted at the R.A.E. during the war to the production of special types of instruments for use on aeroplanes. Many of these are, of course, essential to the successful carrying out of the full-scale aeroplane research.

It is not necessary here to dwell on the facilities which exist elsewhere for laboratory research in aeronautics. Useful work has been done in the wind channel at the East London College ; provision is being made in Cambridge, and at the London University, for research in relation to the training of aeronautical engineers.

Full-scale work on seaplanes and on airships has been carried out during the past year under the control or with the collaboration of members of the N.P.L. staff, and the necessary equipment, instruments, &c., have been constructed at the Laboratory. Reference is made elsewhere to the importance of continuing and extending this work, for which no provision of a permanent character at present exists. Mention is made in the supplement of the further investigations which have been carried out at the R.A.E. during the past year in relation to methods of wind channel construction. These have been directed mainly to the attaining of increased wind speeds with the minimum consumption of power. An air speed of 130 ft. per second has been reached in one of the R.A.E. wind channels. Various improvements have been effected in the auxiliary apparatus and in methods of measurement ; in particular, attention has been devoted to obtaining increased accuracy in the determination of the resistance of airship forms, and in the measurements relating to stability.

6. *Aerodynamics.*—The demands for special tests have been somewhat less numerous during the past year, and it has been possible to make progress with researches of more general character. Among these may be mentioned specially the research on the properties of ailerons, the investigation of the resistance of airship forms and the relation between model and full-scale results, the study of propeller theory, and stability tests of complete models. These last have arisen from the necessity of investigating the stability of new types of aeroplanes. It has been arranged that a complete model of any new type shall be submitted to the N.P.L. for a thorough investigation of its stability, and one of the 7-ft. channels has been set aside for this work. This complete investigation necessarily occupies an appreciable time, but considerable progress has been made, and the results will no doubt be of general interest, and will form an important contribution to the study of aeroplane stability, more particularly in conjunction with the experimental investigation of the stability of the full-scale aeroplanes in flight, for which suitable methods have now been developed.

The research on ailerons deals with the questions of the best form and position, and with the balancing of ailerons for large machines. A complete report on the work has been issued. Considerable attention has been given to the subject of airship resistance, and a large number of observations have been made on airships in flight. The matter is of great theoretical as well as of practical interest and importance, but further evidence is needed for the accurate correlation of full-scale and model results. The resistance to be measured in a wind channel is very small and the attainment of the necessary accuracy is attended with considerable difficulty, while the full-scale measurements are complicated by a number of practical considerations which render difficult the comparison with the model. In view of its importance it is necessary that this investigation should be continued until a successful conclusion is reached, and better facilities for the carrying out of the full-scale experiments should be provided. The work on airscrews has been of a fundamental character and has established the general accuracy of the momentum theory of Froude as applied to the airscrew.

Brief mention may be made of a few of the other more important investigations carried out. Preliminary experiments have been conducted on models of bird-like form. It has been suggested that this form would be efficient for moderately large aeroplanes of such dimensions that the engines could be housed inside the body. The results obtained in the preliminary experiments were promising and on the recommendation of the Committee arrangements were made by the Air Ministry for the preparation of a complete design, on which further tests will be undertaken.

Reference was made in the report for 1918–19 to the investigation of spinning. The work has included interesting experiments in an air channel on the auto-rotation of aerofoils and complete models, as related to the rate of spin of an aeroplane. A full report of the model and full-scale research on the subject of spinning has been published.

The investigation of "scale effect" for the aeroplane wing has been continued and systematic experiments to obtain a comparison between model and full-scale wings are in progress. Attention has been given at the R.A.E. to the improvement of the design of a dynamometer for the measurement of the thrust of an airscrew on an aeroplane in flight. Comparative measurements of the air pressure over the surface of a wing have also been made on the full scale, on an aeroplane in flight, and on models.

Much attention has been given to the problem of reduction of landing speed, and to the cognate question of the increase of control when near the ground. It will be understood that this is a subject of the highest importance in regard to the safety of machines. Experiments on methods of improving the control at low speeds have been arranged for, and the problem has been examined both theoretically and experimentally from various aspects. It may be of interest to mention in this connection the recent design of a new wing of exceptionally high lift coefficient.

In connection with the observations which have been made on full-scale airships in flight, the stability and control of airships have been carefully investigated. As a result of these experiments it has been found possible to effect a considerable reduction in the control surfaces.

Some interesting investigations have been carried out with regard to eddy motion and have led to valuable information with regard to the size and rate of decay of eddies. The effect of eddies on the head resistance to the motion of an airship has been examined in the wind channel. The problem of the parachute has also received special attention ; forms designed on a theoretical basis have been tried on the full-scale and found efficient. The question of the stability of parachutes has been investigated and experiments have been made to determine the effect on the resistance of the porosity of the material used in their construction.

Among other matters to which attention has been given may be mentioned the effect of roughening portions of the surface of an aerofoil, the economic conditions for long flights, the mooring of airships, to which reference has been made in previous reports, and the effect of high tip speeds on the efficiency of airscrews. Professor G. H. Bryan has submitted a mathematical investigation into the effect of the compressibility of the air in relation to the airscrew. Mr. N. A. V. Piercy has presented an interesting report of experiments carried out in the East London College wind channel on the Venturi tube. Papers have been received from members of the N.P.L. staff on the theory of viscous flow ; and valuable results have been reached in the experiments on fluid friction and the flow of fluids over surfaces. Confirmation has been obtained in recent experiments of the view that the flow within a very thin layer close to the surface is laminar and that there is no slipping at the surface. For further details regarding this and other work mentioned above reference may be made to the supplement to this report.

Proposals have recently been put forward that arrangements should, if possible, be made for obtaining comparative tests in the principal wind channels in use in the different allied countries. Such experiments would be of great interest and value in co-ordinating results obtained by different methods and would, it is hoped, economise effort and accelerate the accumulation of reliable data for standard forms. The matter has been taken up actively, and it is hoped to obtain the co-operation of the various laboratories in carrying out such tests.

7. *Seaplanes.*—A number of researches in connection with seaplanes have been in progress in the William Froude National Tank during the past year and have been supplemented by observations on full-scale machines made by the tank staff with the assistance of the flying staff at the Isle of Grain and elsewhere. Among these researches may be mentioned especially those on the effect of beam and loading of floats on propulsive efficiency ; on the effect of impact on the water, including full-scale determination of the pressure over the float or hull ; and on the effect of

loading on stability and of diving at small angles. Experiments are also in progress on flying boat forms designed for alighting on land or water.

8. *Aeroplane Carrier Ships.*—Some further experiments have been carried out, at the request of the Director of Naval Construction, on the flow of air over the deck of an aeroplane carrier ship, and have been verified by observations made on the ship. In this connection it is interesting to note that a successful landing has recently been made on the deck of H.M.S. "Furious," which was designed in accordance with the information obtained from model experiments in the wind channel.

9. *Strength of Construction.*—Continued attention has been given to the important question of strength of construction, and a number of valuable papers dealing with the application of the theory of structures to aeroplane problems and methods of calculation have been discussed by the Aerodynamics Sub-Committee. In October, 1919, by the desire of the Air Ministry, a Load Factor Sub-Committee was formed "to consider and report as to the definite rules which should be adopted to govern the load factors required for all classes of civil aircraft, and upon which certificates of airworthiness may be based."

In addition to members of the Advisory Committee this Committee included representatives of the Air Ministry, the Royal Aeronautical Society and the Society of British Aircraft Constructors. The Committee was assisted by papers contributed by a number of experienced designers, and after full and careful discussion a report which received the unanimous approval of the Committee was communicated to the Air Ministry in January, 1920. For the purpose of the required rules, aeroplanes were divided into the two classes, "Commercial" and "General," the former including only machines to be used for commercial purposes involving straight flying, while the "General" class included machines suitable for military purposes which might at times be subjected to exceptional stress. Load factors and factors of safety were laid down for these two classes, and particulars were given as to the methods of calculation which would be employed in the examination of designs with a view to the issue of certificates. The report was issued to manufacturers by the Air Ministry. Some additional details will be found in the Supplement to this report (p. 46).

10. *Engines.*—During the war a large amount of research relating to engines was carried out at the R.A.E. for the Air Ministry, under the advice and control of the Engine Sub-Committee, of which Sir Dugald Clerk was Chairman. Sir Dugald Clerk resigned this position at the end of March, 1919. The investigation of engine problems has been continued at the R.A.E. during the year 1919–20; experiments on special questions, *e.g.*, cooling and magnetos, have also proceeded at the N.P.L.

One matter to which much attention has been given is the possibility of using fuels with a high flash point in place of petrol and thus reducing the risk of fire on aircraft. Suggestions for a programme of research were originally made by Sir Dugald Clerk and a considerable amount of information has been obtained. Arrangements were made at the R.A.E. for the preparation of a series of fuels of different flash point, and experiments have been carried out with a view to determining the type of engine most suitable for burning fuels of higher flash point. Trial has been made of methods of direct injection and the use of a vapouriser. The experiments are being continued.

One of the difficulties associated with the use of the heavier fuels is detonation. It has been arranged that a research on detonation shall be carried out at the N.P.L., and this has recently been commenced. Some delay occurred owing to the difficulty of obtaining an engineer with the necessary qualifications to undertake the work.

An important research has been in progress during the year in the high altitude test house at the R.A.E. on the effect of variation of compression ratio on the behaviour of an aero-engine at altitude. A report on this research has been received and will be published very shortly. The experiments were conducted over a wide range of conditions as to temperature and pressure, and the information gained is considered to be of much value.

Research on magnetos and ignition has been continued both at the N.P.L. and at the R.A.E. A number of papers have been presented to the Sub-Committee and have led to valuable discussions at meetings at which representatives of the leading manufacturers were present by invitation.

11. *Light Alloys.*—The investigation of light alloys for various purposes in the construction of aircraft and aircraft engines has been continued at the N.P.L. During the war a large amount of experimental work relating to aluminium alloys was very actively carried on at the N.P.L., the R.A.E., Birmingham and Manchester Universities and elsewhere, under the general control of the Light Alloys Sub-Committee which was formed by the Advisory Committee in February, 1917. With the termination of the war the members constituting this Sub-Committee returned to their normal duties, and pending the appointment of the new Aeronautical Research Committee the reconstitution of this Sub-Committee has been suspended. The study of the properties of aluminium alloys has, however, made good progress, and the material accumulated during the war has been collected and will be published at an early date. Sir Henry Fowler was succeeded in the chairmanship of the Sub-Committee by Professor Jenkin, who has prepared a carefully revised report, embodying the information available in the Technical Department of the Air Ministry, on the progress made in the investigation of light alloys,

steels, &c., chiefly as a result of war requirements in the construction of aero engines. This is now in the press and will be issued as an Advisory Committee report.

The work at the N.P.L. has included the further systematic investigation of some of the more promising alloys brought into use during the war which exhibit very valuable properties. Attention has been directed especially to overcoming difficulties which may occur in the production of these alloys on a manufacturing scale. The aluminium alloy containing 4 per cent. copper, 2 per cent. nickel and $1\frac{1}{2}$ per cent. magnesium, which was found of considerable service for castings, has been developed as a wrought alloy, with very interesting results. The constitution of this and other alloys has also been investigated with a view to determining the conditions on which the improvement in properties depends, the mechanism of hardening, &c.

12. *Fire Prevention on Aircraft.*—Early in the year a request was made by the Air Ministry that the Committee would consider what measures might be taken to minimise the risk of fire occurring on aircraft. One measure considered was the use of a heavier fuel, and reference has already been made to the steps taken in this direction. In view of the importance of the matter a Sub-Committee was appointed to investigate the general question of fire prevention and to superintend such experimental work as might be possible in connection with any remedies proposed. The Sub-Committee had the active assistance of the Accidents Department of the Air Ministry, and examination showed that with rare exceptions the fires which have occurred on aeroplanes have been due to the crashing of the aeroplane on the ground, and that fires were much less frequent with rotary-engined aeroplanes than on aeroplanes fitted with stationary engines. Experiment indicated that this was mainly due to the fact that the rotary engine is usually divided by a bulkhead from the body of the aeroplane, and led to the recommendation that such a bulkhead should be provided on all aeroplanes.

The Sub-Committee has also investigated a number of other questions; the fireproofing of the magneto, the position and construction of the petrol tanks, the use of various fire-extinguishing materials, &c. A suitable fire-extinguishing material has been found, which it is believed from the experiments made will be effective in overcoming fires occurring in the air as well as on the ground. An important preliminary report has been presented, which has been communicated to manufacturers by the Air Ministry, and the work is being continued on the lines above indicated.

13. *Meteorology.*—The work of the Meteorology Sub-Committee has been largely directed to the promotion of means of securing systematic information as to the meteorology of the upper air, by means of and for the benefit of aircraft pilots. Considerable attention has been given to the preparation of a form of meteoro-

logical log for the use of pilots in keeping a record of air conditions prevailing on important air routes. The form of log adopted has been put forward for use on the London-Paris air service, and the information that will be accumulated in this manner will no doubt be of great service to Meteorology and of important practical value to pilots. The data recorded include height, temperature, wind velocity and direction, visibility, cloud height, general weather conditions, with remarks as to bumpiness or other peculiarities on special sections of the route.

Much attention has been given to recording and other instruments for use at altitude. The errors in altimeters and airspeed indicators due to variation in the temperature of the air have been investigated. Tables have been compiled for the estimation of the altitude from pressure and temperature records. Methods of determining the wind velocity and direction at heights over land have been investigated, and suggestions have been made as to suitable methods for the determination of cloud heights. Information has been collected as to the distribution of thunder and wind storms.

Enquiry has been made into accidents attributable to weather conditions. It would appear that almost all such accidents are directly caused by bad landings due to fog, or fog and cloud, while only a very small number were due to wind.

Reference has been made above (§ 6) to the study of eddies. The results obtained in the wind channel experiments have been compared with those derived from the investigation of circular storms and other natural phenomena, and it is believed that a valuable advance has been made in the general knowledge of eddy motion, which has an important bearing on meteorology and local meteorological conditions. A considerable number of papers on the subject of eddy motion have been received and are being prepared for publication.

By desire of the Sub-Committee arrangements have been made at the N.P.L. for an investigation relating to anemometers. Experiments will be made at Cambridge with regard to sextants for use in aircraft ; and other instruments for use in air navigation have been investigated. The various papers which have been submitted to the Committee are being re-edited by the Staff of the Meteorological Office, and it is proposed to issue them in due course in a convenient form.

14. *Protection of Kite Balloons from Atmospheric Electrical Disturbances.*—As recorded in the previous report good progress had been made with the investigation of means for the protection of kite balloons from damage owing to atmospheric electrical discharges. Since the termination of the war, however, the staff engaged in conducting the full-scale experiments has been disbanded and it has not been found possible to make arrangements for the continuation of the work. An account of the earlier work has been published.

15. *Fabrics and Dopes.*—The experiments on dopes and fabrics have been continued at the N.P.L. and at the R.A.E. Further information has been obtained as to the deterioration of aeroplane fabrics in the tropics and the conditions on which such deterioration depends. Experiments upon the action of light on fabrics have been continued. The effect of small amounts of acid on the strength of cotton and linen has been examined at the N.P.L., and the inflammability of doped fabrics has also been investigated. A very complete investigation has been carried out at the Admiralty Fabrics Laboratory on the permeability of airship fabrics. The permeability of balloon fabrics by air has been investigated, and the effect of humidity on the weight of the fabric. Some of this work has been carried out in connection with a Sub-Committee of the British Engineering Standards Association, which has been engaged in drawing up specifications for fabrics. In the same connection the effect of the rate of loading, humidity, &c., on the strength of cotton fabrics has been examined. Research has been in progress at the N.P.L. on the physical properties of cellulose acetate, and in particular the advantages of using more viscous acetate, giving a greater film strength.

16. *Special Engineering Work.*—A number of special investigations have been carried out in the Engineering Department of the N.P.L. These include fatigue and impact tests at high temperatures of light alloys, and of valve and other steels ; special furnaces have been constructed for this work to enable tests to be made at temperatures up to 900° C. Low temperature impact tests on steels have also been made. The influence of scratches on the resistance of steels to repeated stress has been examined. The effect of fatigue on soft solders has been investigated in connection with work in progress in the Metallurgy Department. A series of tests has been carried out for the Fire Prevention Sub-Committee on fireproofing of magnetos and the liability of various types of magneto to fire an explosive mixture.

17. *Air Inventions Committee.*—The Air Inventions Committee has continued its work during the past year in close co-operation with the Advisory Committee. Periodical reports have been made to this Committee, and special inventions or designs submitted have been referred for consideration. Particulars as to the duties of the Air Inventions Committee were given in the previous report.

The names of the present members of the Committee are given below.*

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* *Air Inventions Committee.*—Sir Horace Darwin, K.B.E., F.R.S. (Chairman) ; Mr. L. Bairstow, C.B.E., F.R.S., Professor H. L. Callendar, F.R.S., Sir R. T. Glazebrook, K.C.B., F.R.S., Major A. V. Hill, O.B.E. (M.I.D.), Professor B. M. Jones, Professor C. H. Lees, F.R.S., Sir J. E. Petavel, K.B.E., F.R.S., Mr. G. I. Taylor, M.A., F.R.S., Major H. E. Wimperis, O.B.E., R.A.F. (Technical Department), Brig.-General E. M. Maitland, D.S.O. (Airship Department, Admiralty). Secretary : Mr. E. L. Pickles.

18. *Accidents Investigation Committee.*—The names of the present members of this Committee are given below.* In all their work the Committee have received most valuable assistance from the Accidents Department of the Air Ministry, who have systematically collected the necessary data with regard to accidents, and have pursued with great energy and determination and with conspicuous success enquiries into the causes of accidents in particular cases.

Investigations of great importance have been carried out during the year 1919–20. The first of these relates to accidents resulting, in the case of certain machines, from inverted flight. The circumstances in which these accidents have been found to occur have been carefully examined, and as the result of experiments carried out in the wind channel, and in flight, modifications in design have been made to remove the danger. Great assistance in this investigation was rendered by the Accidents Department and by the flying staff of the R.A.E., who reproduced in flight the conditions likely to lead to accident and demonstrated how recovery might be effected. A report on this work is being prepared for publication.

Accidents due to the starting of propellers on the ground have also been under the attention of the Committee. A report on these was submitted to the Air Ministry early in the year, and precautions to prevent their occurrence were suggested.

The accidents to the Felixstowe Fury and to the Tarrant triplane are among other specific cases investigated. These have led to somewhat extensive experiments in the tank and wind channels respectively and the enquiries are not yet completed. Preliminary reports on the experiments have been submitted, and complete reports on the results of the investigations will be presented to the Air Ministry in due course.

19. *Publication of Reports.*—Much progress has been made with the publication of information accumulated during the war. Practically the whole of the available material presented to the Committee has either already been issued or is now in the press. A list of the reports published up to March 31st, 1920, has been printed (R. & M. 650) and is obtainable from H.M. Stationery Office. Individual reports presented to the Committee are published as early as possible after presentation, and particulars of these are included in the monthly list of publications issued by H.M. Stationery Office and are communicated to the Technical Journals.

In presenting this their final report the Committee desire to express their high appreciation of the valuable researches in aeronautics carried out at the N.P.L. and at the R.A.E., respectively. The researches at the N.P.L. have been notable for the development of accurate wind channel methods, the investigation of stability, the study of the flow of fluids over surfaces and the solution of many special problems in aerodynamics ; the determination, on a definite experimental basis, of the most suitable forms of seaplane floats and hulls ; the continuous study of new light alloys suitable for the construction of aircraft and aircraft engines and the perfecting of methods for their commercial production ; and for valuable auxiliary work in the investigation of the properties of fabrics and dopes. The work has been attended with success from the first and has aided greatly the rapid progress of flying and of aircraft construction ; its value and importance have received well merited recognition from the experts in other countries engaged in the study of aeronautics. The full-scale work carried out at the Royal Aircraft Factory, later the Royal Aircraft Establishment, has been no less valuable. The Royal Aircraft Factory initiated in this country full-scale experimental research on aeroplanes and airships, and devised methods which have been conspicuously successful for the investigation on aeroplanes in flight of the many difficult problems associated with the science and art of flying. During the war its staff rendered notable service in the development of aeroplane design and construction and in the study of special manœuvres in flight, facing known risks with an intrepidity no less admirable than that of the fighting pilots and observers of the R.A.F. Many valuable lives were lost in this work, but the results attained justified the sacrifice made and greatly reduced the loss of life due to imperfect knowledge in the design of machines for service use. Very valuable assistance was also given to the Committee as well as to the fighting services by the staffs of the experimental stations at Kingsnorth, Pulham, Felixstowe, the Isle of Grain, Orfordness and elsewhere.

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* *Accidents Investigation Committee.*—Lieut.-Colonel Mervyn O'Gorman, C.B., D.Sc. (Chairman); Sir J. E. Petavel, K.B.E., F.R.S.; Mr. G. B. Cockburn, O.B.E.; Mr. L. Bairstow, C.B.E., F.R.S.; Mr. H. Pippard, Mr. B. Thomson (Secretary.)

The Committee wish also to acknowledge the help which they have constantly received from the Staff of the Air Ministry, which has been of the greatest importance for the efficient discharge of the functions undertaken by them on behalf of the Ministry.

Finally, the Committee desire to record their indebtedness to their Secretaries, Mr. F. J. Selby and Mr. J. L. Nayler, for the successful manner in which their arduous work for the Committee has been conducted. Mr. Selby has acted as Secretary to the Committee since its appointment in 1909. Mr. Nayler has given great assistance in the work during the later years, and, on Mr. Selby's retirement, has been nominated to act as Secretary to the newly constituted Aeronautical Research Committee of the Air Ministry.

Signed on behalf of the Committee,

R. T. GLAZEBROOK,

Chairman.

SUPPLEMENT TO THE REPORT FOR THE YEAR 1919–20.

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Supplement to the Report for the year 1919-20.

In this Supplement specific mention is made of many of the more important problems and matters dealt with by the various sub-committees. The matters are arranged as far as possible under appropriate sub-headings.

AERODYNAMICS.

Aerodynamics Sub-Committee.—This Sub-Committee's work has proceeded on the same lines as in the previous year, including the discussion of all papers on aerodynamics submitted to the Advisory Committee for Aeronautics, the consideration of the programmes of work in hand at the National Physical Laboratory and the Royal Aircraft Establishment, and the receipt and discussion of reports on full scale work on aeroplanes and airships. In addition, the Sub-Committee have paid a great deal of attention to the study of parachutes, to the desirable qualities of aeroplanes as fighting craft, and to the initiation of model tests of complete aeroplanes, with special reference to their stability characteristics. Recently, an Airscrew Panel has been appointed to decide what are the most urgently needed experiments on airscrews, following on a letter from Mr. H. C. Watts, who has suggested laying down a family of airscrews with varying pitch/diameter ratios.

Meetings have normally been fixed a week previous to those of the main committee, ten meetings having been held during the past year. At these meetings some 115 papers and communications have been received and discussed, the more important papers having since been issued by the Advisory Committee.

Fluid Motion.—Fluid motion is one of the many subjects discussed by the Sub-Committee. A most important investigation on the flow of a fluid near a boundary has been completed recently. As a result of experiments on pipes ranging in diameter from 0·269 cms. to 12·7 cms., Dr. Stanton has shown that there is always a finite layer of fluid near the boundary which is in laminar motion even when the flow in the rest of the pipe is well above the critical speed. The experiments cover a range of values for vl/ν from 460 to 325,000, and can, therefore, be considered sufficiently extensive to have demonstrated the existence of this finite layer of fluid in laminar motion ; they also negative the suggestion that a finite slip may occur at the boundary when the remainder of the fluid is in turbulent motion.

The effect of compressibility on high speed streamline motions is another matter that has been investigated. Starting from the conclusion reached in a previous paper, Professor Bryan has shown that the problem of steady streamline motion of a compressible fluid past a fixed obstacle in two dimensions is reducible to one of strain analysis. The method developed is applied to the case of a circular cylinder, and has application to the interpretation of jump card experiments for projectiles fired at a velocity nearly equal to that of sound.

Experiments on Wind Channels.—The main instrument for progress in the science of aerodynamics is the wind channel. In this connection proposals have recently been put forward that arrangements should be made for comparative tests in the principal wind channels in use in the different allied countries. Results obtained in this way should prove of great value for co-ordinating results. Information as to the type and characteristics of the French channels has been received, but sufficient data are not available to enable a true comparison to be made. Further, if the model results are strictly comparable there would be little need for specialising too much on one form of channel.

The N.P.L. type of channel has been the subject of further model experiment. It is considered necessary to use some form of distributor to get good steadiness, a characteristic to which less attention has been paid in other types of wind channel.

With further reference to the above the R.A.E. have instituted an inquiry into the effect of the design of the fan on the steadiness of wind channels. Their experiments have shown that the number of blades does not materially affect the steadiness, but that a fan can be designed of smaller pitch so as to reduce the wind fluctuations from 2 per cent. to $\frac{1}{2}$ per cent. The power consumed in the latter case is doubled.

As a criterion of a channel apart from steadiness, it is considered that the value of the product V D (velocity × diameter), attained for a given power expenditure is a better measure than that given by the ratio of the kinetic energy of the air flowing through the working section to the power supplied to the fan, the latter being the French criterion.

The testing of an airship model presents many difficulties, one of which is the application of a large correction for the pressure drop along the channel. To overcome this difficulty experiments are contemplated on a modified form of wind channel, having no pressure drop along its length.

Airships.—Full scale and model work on airships have progressed well, especially with respect to comparisons between the two classes of experiments. Experiments on stability and controllability have been made with the full scale airship, and in one case the area of fin was successively reduced until a directionally stable ship became unstable. Directly comparable model experiments on this last are in hand.

The full scale experiments include those on the R.26, R.29, R.33 and S.S.E.3 classes, in all of which speed, deceleration, and turning trials have been conducted. Preliminary efforts have been made to measure the airscrew thrust by Stanton's method, using the principle that the thrust is a function of the difference of the total head of air behind and in front of the airscrew disc. When better measurements are available by this method, the determination of the resistance of the full scale airship in flight will be possible to a fair degree of accuracy. Petrol consumption trials have also been made on the R.33 ship, but these await analysis until experiments on models of the airship's screws can be put in hand : this is the fastest ship tested, and it has a speed of 52 knots.

The turning trials of the above airships are of special interest in connection with the determination of their stability and controllability characteristics. A stable ship should fly straight when the rudders are locked amidships, and the rates of turning in a circle with the rudders in this position provide some criterion of its stability. The completion of the model and full scale experiments on the R.33 gave an excellent opportunity of ascertaining what are the discrepancies still existing between model prediction and full scale trial, and were sufficient to show that the differences outstanding could probably be accounted for by carrying out a large number of runs, made at the same rudder setting and over a wide range of speed. Many of the original difficulties have been overcome by the better estimation of the derivative Y_r, which denotes the rate of change of lateral force with turning. In this respect the results of some Italian experiments, made by means of a whirling arm which towed models through water, were of assistance. Further work on the R.29 model, with different fin areas to correspond with the full scale experiments, will show at what stage of reduction of fin area definite instability may be expected.

The mooring of rigid airships is another matter which has received attention. The system of mooring invented by Messrs. Vickers, Ltd., in which the bow of the airship is fixed to a rigid mast, promises well, and will be of the greatest value at all large air ports. The more temporary system of mooring, using a three-wire system, has been modified to an arrangement consisting of three main cables passing over swivelling ground pulleys situated at the apices of an equilateral triangle, and interconnected at the ground base by auxiliary cables to form a quadrilateral : the latter provides a better braking effect. The original three-wire system has already been of service, having been successfully employed in America when the R.34 landed there after the first crossing by airship of the Atlantic Ocean.

Model experiments have been directed to the measurement of resistance, the design of form, and the amount of control. The distribution of pressure over the surface of the airship model, U.721, has been compared with both the theoretical and the experimental pressures on a spheroid. The experiments show that the pressure variation over the nose of a model whose shape in that region is approximately a spheroid can be calculated theoretically—at least as far as the point where the pressure is one-tenth of ρV^2—and this region is the one of most interest in connection with nose stiffening requirements.

The U.721 shape has another interest, because the predicted decrease in the resistance of this form from model experiments was borne out by the full scale experiments on the non-rigid airship S.S.E.3, 100,000 cub. ft. A prediction of the resistance of the R26. was not so satisfactory, for two reasons. Estimates of absolute values are never so reliable as comparative ones; also, the resistance coefficient for the hull of the R.26 was falling markedly at the highest channel speeds. A prediction from the results at the highest speed gives a value 1·2 times that calculated from a deceleration test on this ship, but as the value of the full scale *vl* is 130 times that for the model hull, the gap is evidently in this case too large. To advance our knowledge on these points it is hoped to conduct in the near future experiments on small scale airships.

Apart from turning trials and stability tests, model experiments have been made on balanced controls for rigid airships. The moments measured about the centre of gravity of the R.33 airship, due to control surfaces on the complete model, showed that even though the absolute moment increases with area of control it does not increase per unit area. The effect is attributed to the shielding of the balancing areas by the fins. In later experiments, pressure plotting measurements will be made both on the fins and the control surfaces to clear up this point.

The experimenters responsible for much of the above work have also kept in touch with allied work. They took part in a visit made to France and Italy with the special object of consulting as to the methods of design, experiment, &c., in the different countries. Mention may be made here of the interesting design of the Italian Forlanini type of ship suitable for construction up to about a million cubic feet capacity. The semi-rigid form was also noted as providing a good design for carrying capacities intermediate between the small non-rigid and large rigid airship. No very complete efforts appear to have been made on Italian ships to reduce resistance, circular tubes, &c., remaining unfaired. During the same visit co-operation was secured with the Americans, details of the American "dynamic neutraliser vane" for automatic control and of the "F.B." Goodyear non-rigid airship being obtained.

Aeroplane Carrier Ships.—In response to requests from the Admiralty, work on aeroplane carrier ships has been continued. Previous experiments on the "Eagle" have suggested the advisability of rounding down the stern end of the flying deck.

Similar experiments gave the same result for the "Hermes," for which it was recommended that a slight cambering of the last 80 feet of deck would be an advantage by reducing the amount of unsteadiness in the flow of air over the normally flat deck. Shortly, the Admiralty will commence a lengthy programme of experiments on an aeroplane carrier; the experiments will have a direct bearing on the wind channel tests already completed.

Other experiments on similar problems have been conducted. They related to the protection from the wind of men stationed in the fighting tops or on the bridge. Model experiments at the N.P.L. have demonstrated that adequate shielding could be readily obtained by small modifications in design that did not interfere with naval requirements.

Aeroplane Wings.—Tests on wing sections still form a portion of wind channel work. An advance in the design of aeroplane wings has lately been made possible by the introduction of a new feature which renders possible the conversion of a high speed low lift wing into a high lift wing. The experiments on this invention are still of a preliminary nature, but sufficient data are available to show that the speed range of aeroplanes in the near future will be very greatly increased.

Experiment has continued on a number of wing sections of the fixed camber type. The Fokker thick aerofoil section has been tested and gave a maximum lift coefficient of 0·765 compared with 0·845 for the R.A.F. 19 section, and similar values for some of the American high lift wings, such as U.S.A.T.S. 5. Two Bristol aerofoils with characteristics similar to the section R.A.F. 15, together with modifications of the last-named, have been tested, but they provide no new developments; similar remarks apply to the biplane test of R.A.F. 19, with maximum lift coefficient of 0·797. In considering these and other sections, attention may, however, be drawn to a method of comparing the relative merits of various aerofoil sections based on the principle of plotting horse power necessary against forward speed.

Of greater interest is the result of an investigation on the performance of a wing of variable camber. The form of the section is variable by means of a narrow front flap and a fairly wide rear flap, both being moved simultaneously so that the new chord is always parallel to the original. A strut shaped section was taken and the resulting aerofoil was as good as R.A.F.15. Similar experiments on a better primary, such as R.A.F.15, promise a greatly increased performance: these are now in hand. The form of cambered wing here tested had not the disadvantage of a large change in the position of the centre of pressure such as is usually associated with the introduction of flaps on the wings.

Two other experiments on wing sections are worthy of mention. At East London College the flow in the rear of a triplane at small angles of incidence has been carefully explored over a depth of 3 or 4 chords and a distance behind the model of 5 chords. The downwash was found to be more persistent than is the case with a monoplane and to be fairly evenly distributed across the field between the top and bottom planes. For purposes of computation the monoplane results for a different section may be employed without great error, and the triplane interference defined by the decrease in the effective lift.

The other experiment related to the roughening of the surface of an aerofoil. A roughening of the under surface with fine sand produced little effect and with coarse sand a great decrease in efficiency. A roughening of the upper surface with fine sand near the region where the tangent to the surface is horizontal gave a small percentage increase in the lift/drag ratio over the whole flying range.

In connection with controls, a useful and extensive series of aileron tests has been completed at the N.P.L., where the effect of a variation in aileron chord and span, in wash-out and in taper, was examined. The "Panther" type of aileron was found to be more efficient than the S.E.5 type and to compare well with that of the B.E.2C aeroplane. In other tests on balancing, the position of the hinge for complete balance, the variation of balance with incidence, the effect of yaw and gap, and the desirability of making the ailerons of full wing section were all tested. The information gained from these experiments should be ample for the design of ailerons with any desired amount of balance. A few comparative tests on the "horn" type of aileron are also contemplated.

Aeroplane Parts.—Only a small number of tests have been made on aeroplane parts. The ratio of the resistance of inclined struts to their normal resistance has been found to be greater at all angles than the corresponding ratio for circular wires; the curve for the resistance of the latter for different angles (α) of inclination varies little from the curve of $\sin^3\alpha$. The distribution of pressure over the tail plane of B.E.2C has been measured, and shows that the load on the elevators may be taken without serious error at 0·3 of the chord of the elevators from the hinge and that the load increases about 20 per cent. towards the tips. Contradictory results have been obtained for the resistance of certain forms of undercarriage; the fairing which in the case of the model reduces resistance may in the case of full scale be only a slight improvement or even increase the resistance of that part. It should be noted, however, that it is very difficult to evaluate the full scale data, especially with regard to interference effects. The only model body tested has been the Bristol Pullman, which has a shape of low resistance.

Models of complete Aeroplanes.—A number of models of complete aeroplanes have been tested in the N.P.L. and R.A.E. wind channels. They include the one-twelfth scale model of

B.E.2E, fitted with R.A.F.15 and R.A.F.18 wings, two Woyevodsky designs, Messrs. Vickers' "Valentia," and the Tarrant "Tabor" triplane. The foremost is of interest for comparison with full scale trials of the same aeroplane, and to the appropriate section of this Supplement reference should be made. No comment is necessary on the Valentia, but the historic accident to the Tabor and the radical departure of design in the case of the Woyevodsky need mention.

Experiments in the wind channels have shown that the "Tabor" would be satisfactorily stable in flight at all speeds except the actual stalling speed, while the proximity of the ground increases the stability. They, on the other hand, show that with the machine taxi-ing at the observed attitude and speed at the time of the accident, the effect of the upper airscrews, when suddenly switched on, would be to cause the machine to turn over on its nose if the controls be not moved. The experiments made evident that careful investigation of all large aeroplanes or unusual designs of machines by wind channel work will operate to reduce or nullify the number of accidents; thus the Air Ministry's intention to test models of large aeroplanes such as the series now in hand at the N.P.L. is well warranted by experience.

The Woyevodsky design of aeroplane has a bird-like form and an aerodynamic efficiency which justifies the development of this type of aeroplane. The best model tested, which, however, was not complete in all details, was superior to existing types of large aeroplane over the whole flying range. It is understood that the Air Ministry, in view of its good aerodynamic qualities and of the estimated weight of structure made and submitted by the designer not being prohibitive, have given encouragement to the further development of a more detailed design.

Full Scale Work on Aeroplanes.—Progress in full scale work on aeroplanes has continued at the R.A.E., most of the work being conducted in co-operation with channel experiments on the same aeroplanes. In addition, attention has been paid to other matters, such as the adequacy of control on landing and economy in flight.

Full scale experiments on five wing sections, R.A.F.14, 15, 17, 18 and old B.E.2C, have been completed. The experiments were done at full engine power, and also with the engine throttled, on the B.E.2C and B.E.2E aeroplanes with R.A.F.1a engines. The analysis of the results proceeds from performance tests with the help of engine and airscrew calibrations and from model tests of parts of the aeroplane. It is estimated that the probable error of a point on a mean full scale drag curve is still about 0·001 in k_D, the drag coefficient, so that a more precise method is needed for very accurate data. The experiments are, however, sufficient to determine the shape of the drag curve except at the smaller values of the lift. What is most urgently needed for further progress is the design of a better form of thrustmeter and a more accurate inclinometer. Direct measurement of the drag of a detachable wing structure is also contemplated. Similar comparative work has been carried out with regard to the determination of the centre of pressure on the wings. These experiments shew an important difference between the model and full scale which requires further investigation.

Gliding tests on a modified S.E. 5 aeroplane gave a marked improvement in the decrease of the fuselage drag when fitted with a spinner (30 per cent. at 100 m.p.h.), and are of interest for similar designs. The exploration of the rotational slipstream of a tractor biplane in continuation of those on a pusher has been made, showing that solely from the point of view of eliminating turning tendency in straight flight, it is better to place the fin and rudder below the tail plane of a tractor. Experiments on the maximum control of elevators of different sizes showed that elevators with 35 per cent. of the total tail plane area give the best results, having smaller forces and greater maximum control than larger sizes.

In connection with flight tests attention has been drawn to the German experiments on the Friedrischshafen aeroplane and the corresponding wind channel tests at Göttingen. By assuming a curve of pressure distribution of semi-elliptical form across the span of a wing, and introducing a circulation round the wing, the Göttingen School have arrived at a number of formulæ for the effect of span, biplane, scale effect, &c., which agree well with practice. For the same lift coefficient in full scale and model monoplanes the differences between the drag coefficients are proved to be proportional to the square of the lift coefficient, with a scale effect of about $\frac{1}{5}$th in favour of the former. These results are true in part, but appear to need modification, especially in the scale effect correction.

The importance of adequate control at low speeds is a matter concerning full scale work which is now receiving much attention. It is considered that an increase in the controllability of an aeroplane when flying at a speed just below stalling would enable pilots to land in smaller aerodromes and greatly reduce the risk of forced landings. Calculation shows that the landing distance is reduced by flattening out gradually instead of abruptly, and that the most efficient schemes in aid of the further reduction are variable camber wings and reversible pitch airscrews. It is possible that the difficulties may be met in part by the newly-invented wing, to which reference has already been made.

Another question of commercial interest is the consideration of the economical conditions of long flight. The empirical analysis previously published has been applied to assumptions more nearly approximating to actual conditions of flight. The general conclusions are not found to be invalidated :—viz., fly always at a certain best attitude and at as great a height as possible.

Inquiry has been instituted into the relative merits of various types and arrangements of power units, with special reference to the evaluation of the minimum amount of cooling (and thus minimum aerodynamic resistance) needed for standard types of engine, to the employment of convertible energy otherwise wasted and to the need of the determination of the respective merits of direct driven and geared down propellers. Comparisons between the economic flight of different aeroplanes and airships have also been attempted.

Stability of Aeroplanes.—The main experiments on the stability of aeroplanes during the year 1919-20 have been in the direction of full scale experiment during a search for the explanation of various types of accidents: an account of this work is given in a special section below. Other progress has been initiated in the commencement of tests on a number of complete aeroplane models. With each of these models a complete determination of all their derivatives is to be made, giving an increase in practical data of inestimable value to designers. In addition a few model experiments and some theoretical investigations have been undertaken.

The more interesting channel work has been the development of a method for determining the rotary derivatives more accurately than in the past. One method involves the oscillation of the model about a spindle through the centre of gravity, the two ends of the spindle being of cruciform section. This design of spindle reduces the amount of solid friction to a small quantity and is considered preferable to the former method in which the spindle rotated on point bearings. Another method employs a suitable wire suspension enabling the important rotary derivatives, M_q and N_r to be directly determined without the necessity of applying corrections for losses due to friction and hysteresis. Difficulty has been experienced with this last at high wind speeds, but by adding inertia to those moving parts which are situated outside the channel walls, the method has been greatly improved.

The R.A.E. have developed the ordinary equations of stability for the case of free elevators and have found approximate formulæ for the resistance derivatives in the usual criteria, which latter are connected with the variation of elevator angle and control force in steady flight. The results show that the slope of the curves of control force and elevator angle against incidence can be used as stability criteria for free and fixed elevators respectively. The stability derivatives of an airscrew have also been carefully determined. Only four are found to vanish. Those of chief importance are X_u and M_u for longitudinal stability and Y_v, N_v and N_r for lateral stability.

A comprehensive paper on the longitudinal stability of an aeroplane has been prepared by the R.A.E. staff, giving formulæ for calculating derivatives, with convenient approximate expressions. The contributions of the airscrew to the various stability derivatives have been obtained, and formulæ given to calculate these for any variation of thrust and torque with speed and revolutions.

One other paper on stability from the Directorate of Research deserves special mention. Calculations have been made of the periods and damping factors of aeroplane oscillations, and a comparison with the observations of full scale experiment. The paper covers the cases of the evaluation of the longitudinal derivatives of an aeroplane, both with the elevators fixed and free, and also with and without an allowance for downwash and slipstream. When full allowance is made for both these factors, the calculated values of both damping ratio and period show promise of good agreement with the full scale tests ; in estimating the period it is apparently immaterial whether the elevators are regarded as fixed or free.

Accidents Investigation Committee.—The attention of the Accidents Investigation Committee has been mainly directed to the discussion of problems relating to spinning accidents and to upside down flying. In both cases the Committee consider that all difficulties can be met by suitable care in design, but whether an aeroplane is to be regarded as a better fighting machine when stable or unstable seems to depend mainly upon the individual predilections of the respective pilots.

Mention was made in last year's report of the investigations relative to spinning carried out more specially at the R.A.E. Since this period some subsidiary questions have been reported on, and the whole summarised and reported by the R.A.E. in a communication, now published. In the summary attention is drawn to the many questions investigated—the general characteristics of a spin, the experimental results for different types, the mathematical theory of the manœuvre, the model tests on the autorotation of an aerofoil and on an aerofoil twisted at an approximate angle to represent the action of the wind forces on the aeroplane, and finally the pilots' reports as to their tests on spinning stability. In connection with this it is of interest to note that an unstable aeroplane (centre of gravity far back) will spin more readily than a stable one, and is more liable to change from a right hand into a left hand spin when the pilot attempts to bring the aeroplane into normal flight ; further, that calculations on the " strip " theory, assuming the wind forces on each section of the wing can be separately added together, are well justified and applicable to full scale.

Upside down flying, the other question investigated, has provided much matter for discussion. In the past strong objections have been raised to using stable aeroplanes and there is still a large school of pilots of this way of thinking. For training and commercial aeroplanes it is now generally agreed that stable aeroplanes are preferable to unstable ones. For fighting purposes a difference of opinion still exists. The controllability of an aeroplane is to some extent dependent upon the amount of its stability or instability, but it has not yet been proved that it is always possible to make a stable machine as readily controllable as an unstable aeroplane ; many fighting pilots definitely prefer the latter because it is said to give a more responsive gun platform. Inquiry is being made as to the success of different types of machine, with each characteristic, in their flying capacities during the war : the matter is still under discussion.

As to upside down flying, model experiment on an S.E.5 suggests that there is usually only one flying position, either normal or inverted, which is stable for a given control setting. Thus an aeroplane longitudinally unstable in normal flight will be stable when inverted, and *vice versa*. Full scale experiment shows other characteristics in favour of the stable machine, for the latter does not tend to hang at the top of a loop, nor to go into an " over the vertical " nose dive. Further experiments on an unstable aeroplane are in progress.

The Accidents Committee have discussed the above experiments on inverted flying, and have concluded—(*a*) that an oscillation diagram of each new type of aeroplane for longitudinal motion should be taken and certified as satisfactory, if stable ; (*b*) that the centre of gravity should be certified within certain limits ; and (*c*) that the lateral stability of aeroplanes should be similarly investigated. The last, (*c*), is being considered, and some preliminary experiments have been commenced.

Airscrews.—With a further accumulation of experimental knowledge the development of airscrew theory has advanced. The last important step in this direction was the introduction of the now well-known " inflow " theory, which increased greatly the accuracy of predicted performance. The next important advance will probably be associated with the publication of the results of pressure plotting experiments on the blades of an airscrew, a type of experiment not previously attempted owing, in part, to its difficulty. Other interesting work on the mutual interference between the various blades has been completed at the R.A.E., an experimental investigation into Froude's momentum theory at the N.P.L., and preliminary trials of the performance of airscrews with high tip speeds at the R.A.E. ; the laying down and testing of a family of airscrews with varying pitch diameter ratios is also contemplated. To co-ordinate all the above work an Airscrew Panel of the Aerodynamics Sub-Committee has been formed.

In order to investigate the mutual interference between the blades of an airscrew wind channel measurements have been made at the R.A.E. of the lift and drag of an aerofoil both alone and with the interference of a cascade of aerofoils, the arrangements tested covering all cases likely to occur in practice in an airscrew. From these data, allowances for blade interference of an airscrew have been deduced in the form of corrections to be applied to the ordinary aerofoil data used, and have been found to account completely for the differences between an airscrew as tested with various numbers of blades. The blade interference is found to account for by far the larger part of the outstanding discrepancy between the simple aerofoil theory and experiment. The experiments also indicate that it is not possible to represent the mutual interference of the blades by the assumption of an inflow which is any constant fraction of the ultimate slipstream velocity.

The airflow around an airscrew has been determined to ascertain to what extent the momentum theory of Froude is realised in practice. The integral of the total head over a section immediately behind the airscrew was found to be approximately equal to the thrust of the screw. At climbing and maximum efficiency the ratios of the augmented velocity in the minimum sectional area of the outflowing stream to the inflow velocity were 1·80 and 1·65 respectively. Finally, a comparison between the measured and hypothetical airflow establishes in a general manner the soundness of the underlying conception of the Froude momentum theory and demonstrates the utility in practice of such a theory ; in general, the disagreement may be considered as less than 10 per cent. In connection with this work the method of correcting the speed of advance for the effect of channel constraint on the airflow of the screw under test in the channel has been carefully considered.

Experiments have been made on models of several airscrews designed for the 150 h.p. ungeared Hispano Suiza engine fitted to the S.E.5 aeroplane. A comparison between these and the full scale tests on the same airscrews will be made, and will provide useful data for comparative performance, especially as to the combined efficiency of airscrew and body. In particular it is hoped to estimate the effect of blade shape on the twisting of the blade under load.

With the increase in power of aircraft engines it is becoming expedient in many cases to employ airscrews with relatively high tip speeds. There is, however, a limit in tip speed beyond which it would be very inefficient to run an airscrew. Nothing is known as to the performance of airscrews with tip speeds greater than the velocity of sound, but at tip speeds approaching that value the usual airflow breaks down completely. Experiment has demonstrated that as the tip speed increases to this critical value, the slipstream rapidly diminishes and ultimately vanishes when the velocity of sound is reached. Air then appears to be sucked in from both sides of the disc and exhausted at, or close behind, the periphery ; under such conditions the thrust becomes very small and may vanish. The power absorbed, on the other hand, increases continuously with the cube of the revolutions. Full scale tests under similar conditions are contemplated.

With airscrews running at high tip speeds no discontinuity in the sound emitted occurs as the velocity approaches and exceeds that of sound. The maximum sound occurs in, or slightly in front of, the plane of rotation and minimum sound along the axis of rotation; the sound emitted near the critical velocity of sound can be heard at great distances. In other experiments on the sound from ordinary airscrews few definite conclusions have been reached. The noise emitted is confused, although musical notes can often be picked out corresponding to the product of the number of blades and the revolutions per second; also, the distance of audibility appears to be independent of tip speed. The crackle of an airscrew is attributed by Professor Bryan to the hearing by the observer during a certain definite fraction of each period of the sounds emitted at three different points on the orbit reaching him at the same time.

A little work has also been carried out on variable pitch airscrews, including the determination of empirical formulæ with applications to the prediction of aeroplane performance. It seems possible to predict accurately the performance under various conditions. Attention has also been paid to the determination of the vibration speeds of airscrew blades, which appear in all cases to be greater than the normal speed of an airscrew.

Parachutes.—Questions relating to parachutes have engaged the careful attention of the Aerodynamics Sub-Committee, which has received reports both from the N.P.L. on the many experiments conducted in the wind channels and from the Directorate of Research with reference to full scale trial. Attention has been directed more especially to the design of a parachute of small bulk, light weight and satisfactory stability. The results of model experiment are in advance of full scale, but the latter are being pushed forward. In the later experiments it is proposed to observe the flight of the parachutes by means of the Hill mirror method, as there are outstanding differences in observation which cannot well be determined by less accurate methods.

Drops of parachutes of most of the well known types have been made, these types including the Spencer, Guardian Angel and certain French parachutes. Conical parachutes and others with vents of varying sizes have also been experimented with. Most, if not all of the above, develop pleats in their surface and exhibit a pumping action when in flight. Pleats decrease the area presented normal to the direction of motion and are in this respect inefficient, as it is most desirable that parachutes should be of the least possible weight and bulk.

Mr. G. I. Taylor has investigated the problem of designing a parachute which had a zero circumferential tension everywhere throughout the fabric and a design of parachute based on his investigation has provided a starting point for research work. As designed, the Taylor parachute is a great improvement on other types, both as regards decrease of bulk and weight and also increase in stability; further, it does not pleat in folds during flight.

The values of the tensions in the fabric and the stability characteristics of parachutes have been thoroughly investigated. Resulting from this work, the N.P.L. have designed a parachute with a small positive hoop tension everywhere, giving somewhat greater steadiness in flight than the Taylor design of zero hoop tension at only a slight sacrifice in weight and bulk; the form becomes more conical with increase in the value of the hoop tension.

Instruments.—In connection with meteorology, experiments on several types of instrument have been conducted and to the proper section of the Supplement reference should be made. Design of other instruments has also proceeded.

The R.A.E. have constructed a very satisfactory modification of the Chattock & Fry tilting manometer, designed to measure heads up to 6 inches of water. Its special use has been for the high speed wind channel at the R.A.E., and for measurement of the large suctions occurring over aerofoils. The manometer, described in a report already issued, has the following advantages over the older design:—(1) It occupies less space; (2) the glass work is much simpler and less fragile; and (3) it can be used on a less rigid support.

At East London College the immersed Venturi has been tested in various forms with special reference to its use in aircraft for purposes of power transmission. A large number of single and double Venturis were examined; finally, one double Venturi was selected and experiments carried out in relation to its use as a source of power with the employment of six inflow tubes of graduated size. The pressure head in the double Venturi depends normally on the 2·2th power of the speed, a change of index occurring at a speed of about 30 ft./sec. More efficient forms of single Venturi have been tested at McCook Field, U.S.A., and to the description of the American experiments reference should also be made.

A recording three-dimensional accelerometer for use in aeroplanes has been designed by Dr. Searle while at the R.A.E. The instrument will enable the accelerometer ratios in three mutually perpendicular directions to be simultaneously measured. In essentials it consists of three separate staffs (portions of the apparatus free to take up accelerations in a given direction), the magnitudes of whose angular movements are transferred by optical methods to, and registered on, a single recording film. The instrument has also the advantage over previous designs that it does not require the construction of delicate quartz fibres.

Special Matters.—The analysis and graphical solution of the differential equations of mathematical physics have been developed at the N.P.L., so as to be applicable to certain special problems. It has been shown that the characteristics of any physical problem expressed in the form of a differential equation with definite boundary conditions depends upon the presence in the equation of certain non-dimensional class variables round which the analysis must centre, and, therefore, in terms of which an expansion may be obtained.

In the light of this the standard method of expansion in a power series of the independent variables appears at once non-instructive and artificial. A method has accordingly been developed, showing how the coefficients in the expansion can be obtained in the case of many problems of aeronautical interest, and that the convergence of the series is rapid.

The paper, now published, provides a new and powerful instrument for analysis of many engineering and physical problems.

INTERNAL COMBUSTION ENGINES.

Internal Combustion Engine Sub-Committee.—Owing to a considerably reduced pressure of work and to a greatly reduced staff available for research at the Air Ministry and at the Royal Aircraft Establishment, the volume of work supervised by this Sub-Committee during 1919–20 has been greatly reduced below that previously required during the war. Another aspect of the situation, viz., the possibility of instituting more lengthy researches, has also helped to reduce the amount of committee work necessary ; on the other hand, it has tended to the production of more valuable work by the experimental staffs, who are now better able to investigate exhaustively the work undertaken by them.

The Sub-Committee have met four times during the past year, and have discussed some twenty papers submitted to them. The most important of these have been published, together with earlier work previously kept confidential on account of the war. The major portion of the papers will be included in a special publication dealing only with internal combustion engines.

The investigations at the R.A.E. on engine problems have been continued during the past year, with special reference to high flash-point fuels, in order to obtain greater immunity from fire on aircraft. At the N.P.L. the researches on magnetos and ignition problems have been advanced, other work on the same subject being conducted also at the R.A.E. ; in addition, a research on detonation in aircraft engines, on lines suggested by Sir Dugald Clerk, has been commenced at the N.P.L.

High Flash-Point Fuels.—Fuels with boiling points between 140° and 150° C. have been used in single cylinder tests at the R.A.E. ; the boiling point was determined by the consideration that the fuel should be safe from ignition at ordinary temperatures. The best of these fuels gave about 94 per cent. of the power developed on standard spirit with an increase in fuel consumption of 9 per cent. by weight. The experiments were only of a preliminary nature, but they are now being followed by aeroplane flight tests, after the conclusion of which it will be possible to state more clearly what is the loss of efficiency incurred if a fuel of high flash-point is used in aircraft engines.

The development of the design of aircraft engines using heavy fuels is proceeding at the R.A.E. on two lines—(1) engines using direct fuel injection, and (2) engines using vapourisers. The former is first receiving attention in the conduction of tests on a single cylinder unit employing a direct injection of fuel (petrol and paraffin) at the beginning of the suction stroke. In later experiments it is hoped to make the injection during the compression stroke and thus obtain a more economical consumption. For airships a safe fuel can be more readily introduced, as increases in weight of fuel and engine do not assume such importance as with aeroplanes ; in the case of the latter an economical consumption is essential. The use of heavy fuels is also closely related to the difficulties arising with detonation ; these difficulties and the problems associated with them are now being investigated at the N.P.L., as already stated.

In order to gain some idea of the disadvantages associated with the use of high flash-point fuels, the effect of employing paraffin as a fuel in various types of aeroplanes and airships has been considered. It has been shown in a report since published that by using a vapouriser the power is reduced for a given weight of engine to 65 per cent. of that obtained with petrol, and the consumption of fuel is increased by about 20 per cent. A change of engine characteristics of this magnitude would seriously affect the flying possibilities of a small scout by reducing its useful load to a very small amount ; in the case of a flying boat the reduction in useful load is about 40 per cent. Similar conclusions apply to airships, but the percentage effect is much smaller.

Compression Ratio and Altitude.—At the R.A.E., experiments have also been made to determine the effect of variation of compression ratio on the behaviour of an aero engine at altitude. The tests were made on a single cylinder trial engine in the high altitude test house at the R.A.E. Material increase in b.h.p. was obtained under high altitude conditions by the use of high compression, the increase of compression ratio from 4·8 to 7·6 giving 30 per cent. increase of b.h.p. at 25,000 ft. Under all conditions as to compression ratio, the petrol consumption for the same absolute air pressure was sensibly constant, and as the air pressure was varied was sensibly proportional to air pressure. The thermal efficiency attained a maximum at a given air pressure, this pressure decreasing as the compression ratio increased. The effect of air temperature was also examined, and it was concluded that over a wide range of conditions as to temperature and pressure the b.h.p. was inversely proportional to the absolute temperature of the charge in the induction pipe.

The experiments make it evident that by suitable arrangement of the controls it should be possible to maintain constant power from the ground up to the altitude at which the engine is adjusted to run on full throttle ; they are being continued.

Air-cooled Cylinders.—The development work on air-cooled cylinders has made good progress and present day air-cooled cylinders are capable of performing equally well under the same full-load conditions as the most efficient water-cooled types. The improvements, principally to cylinder cooling fins and shape of combustion chamber, have permitted the increase of the compression ratio from 4·6 to 5·3 with a gain in power and reduction in fuel consumption.

The cylinders are of composite construction with aluminium head cast on to a steel barrel, and a series of tests has been carried out to determine the most satisfactory shape of key joint between barrel and head to give unity and gas tightness.

Cylinders designed and made at the R.A.E. of the same bore and stroke as the Dragonfly type were mounted on a Dragonfly crankcase and the power was increased from 295 b.h.p. at 1,650 r.p.m. to 350 b.h.p. at the same speed, at the same time decreasing the consumption from 0·64 lbs. to 0·54 lbs. per brake horse power hour. The added weight was about 40 lbs. Other cylinders were made to replace those of the Wasp engine, keeping the bore and stroke the same, and in addition modifications were made to improve the fuel distribution. The power was in this case increased from 150 b.h.p. to 185 b.h.p. at 1,800 r.p.m., the consumption being at the same time reduced from 0·59 lbs. to 0·49 lbs. per brake horse power hour. The added weight was 27 lbs.

In order to obtain the performance of large air-cooled cylinders an 8 in. bore and 10 in. stroke cylinder has been made and is now under test. Much trouble is being experienced with the valve gear. An 8 in. × 11 in. water-cooled cylinder has also been made and is under test. This cylinder has been delayed by valve gear trouble the design of which for large high-speed engines requires careful consideration.

A cylinder with aluminium head secured to the barrel by bolts and nuts has been experimented with and may possibly give results almost equal to those obtained from a cast on head cylinder.

Direct Injection of Fuel.—Outstanding advantages such as equal distribution, use of higher flash-point fuels, the minimum of fire risk and a lower weight power ratio are apparently to be gained with engines operating with directly injected fuel, and considerable work has been done on single cylinder units so fitted.

Turbo Compressor for Liberty Engine.—A large number of experiments have been carried out in the High Altitude Test House on a 400 h.p. Liberty engine fitted with a Rateau type turbo compressor to provide intake air at increased pressure at altitude. The results are very promising and ground power has been developed under conditions corresponding to an altitude of 15,000 feet.

High-Tension Electrical Indicator.—This instrument has been specially designed to enable indicator diagrams to be taken simultaneously from the various cylinders of a multi-engine in flight in order to establish definitely such data as the "Variation of Engine Power with Altitude," and to provide an aid to perfecting the distribution of mixture to engine cylinders fed from a common induction pipe. The bulk of the work has been confined to developing and perfecting the detailed fittings.

Magneto Research.—The experimental work at the N.P.L. on magnetos has been concentrated on the determination of the effect of the effective inductance, effective resistance, and self-capacity of magneto windings on performance. The results of the investigation include measurements of the inductance and effective resistance of the primary and secondary at various frequencies up to 35,000 per second ; and of the self-capacity, self-resonance, and dielectric loss of the secondary winding. The iron and stray loss was calculated by four different methods : the general conclusion was that the efficiency was about 25 per cent. The influence of the armature brass end plates was found to be small. The effect of the use of thin iron laminations in rotating armatures was examined. To obtain the full benefit of the use of thin laminations as suggested by theory it would be necessary to redesign the magneto, since the improvement obtained under one set of conditions is often accompanied by disadvantages under other conditions.

As regards future work it is hoped to deal with the more abstract questions at the N.P.L., leaving the manufacturers to attack questions immediately affecting production.

Magnetos and Electrical Ignition.—The effect of plug leakage on the performance of electrical ignition systems has been investigated at the R.A.E., both theoretically and experimentally. The work has been extended to various types of magnetos and a general basis for design in order to avoid the serious limitations produced by plug leakage has been developed. It has been shown in accordance with the theoretical investigation that there exists an optimum number of secondary turns which gives the least reaction to shunted resistance.

In view of the proposed general adoption of braided high-tension ignition cable and the serious effect the addition of shunted capacity has on the sparking performance of ignition systems, a full series of tests has been carried out on all the leading types of magnetos. Incidentally, an approximate method of determining the capacity of the secondary winding has been developed.

The great theoretical advantages which may be derived from using laminated magnetic circuits of magnetos of the very thinnest sheet "Stalloy" iron are being subjected to practical tests. Various laminated inductors, pole shoes, and cores using thicknesses down to 0·004 in. are under investigation.

Before very much progress can be made in applying theoretical investigations to magneto design, suitable methods of measuring the various inductances, capacities and effective resistances of the windings must be developed. The difficulty consists in getting the necessary current at the required frequencies (up to 20,000 ∼ per second). A valve oscillation generator set of sufficient power has been installed and suitable methods of measurement are being devised.

The contact breaker of an ignition system is one of the vital sources of weakness and every attempt is being made to secure improvement in this element. A very complete enquiry into the causes of voltage irregularities of magnetos has been made and the necessary apparatus has been designed for measuring the various characteristics of contact breakers.

Considerable attention has been given to developing and perfecting laboratory equipment for carrying out all the necessary type tests on magnetos. A series of 8 standard types of magnetos is being put through as comprehensive a series of tests as possible in order to obtain more complete information than exists at present of the capabilities of the various types. Much time has also been devoted to the question of devising a reliable form of spark gap voltage test. One special piece of apparatus that has been developed is a mechanical device for separating the initial part of a magneto discharge from the succeeding arc. Measurements of the wave form of secondary E.M.F. have also been made, using a very refined form of high-speed contact maker coupled up to a thermionic valve.

METEOROLOGY.

Meteorology Sub-Committee.—The Meteorology Sub-Committee has held nine meetings during the past year, and has discussed some twenty-four papers submitted to them, in addition to certain general problems brought to their attention. They have continued to encourage research work in meteorology, more particularly with reference to investigations carried out in the upper air, and have at all times promoted co-operation between theory and practice in general meteorological work.

Of the questions occupying their attention last year, it has not been possible to continue the investigations dealing with the wind barrage at East Fortune, owing to the dismantling of the station, but it is hoped that at some future date facilities will be made available for continuing work of this nature, which has a direct bearing on the analysis of the structure of the atmosphere.

Of new matters, perhaps the most important step initiated by the Committee during the past year is the drafting of a form of air log for the use of pilots in keeping a record of the air conditions prevailing on important air routes. The form of log put forward for use will shortly be in the hands of pilots flying on the London-Paris air service. In this connection the Committee wish to place on record the help rendered them by the Aircraft Transport and Travel Co., and by their managing director, General Festing, who has also assisted the Committee in preparing the draft form of log. The information accumulated by the above means is expected to aid materially in the preparation of forecasts, as well as in accumulating data on the conditions of the upper air. Its value in assisting civil aviation, if adopted on all regular routes, should be of the utmost importance.

The more important papers received by the Sub-Committee are published separately, from time to time, by the Advisory Committee. In addition, all the papers on meteorology and allied subjects which have been issued by the Advisory Committee since its formation in 1909 will be published together as a separate volume. They contain results of value to meteorologists; and to make them more accessible they are being edited, prior to publication, with references to other work dealing with similar matter. For convenience, the matters dealt with by the Sub-Committee are grouped below under separate headings.

The Upper Air.—In connection with work in the upper air, the errors in the readings of altimeters and airspeed indicators, due to the variation of the temperature of the air in S.E. England, has formed the subject of a paper by Mr. G. M. B. Dobson. It fills an important gap in our knowledge of the subject, and has been issued for publication. At an early date it is proposed to tabulate in the same way the errors for other parts of the world.

Dealing with the estimation of heights, a table is being compiled giving the height of an aeroplane in terms of pressure differences under average conditions of temperature and pressure in Europe between the latitudes of 45° and 55° N. The pressure differences will be given in millibars and the heights in feet, the main use of the table being the estimation from the aneroid record of the height reached by aircraft. Another table, giving the mean observations of temperature at heights during the performance trials of aeroplanes at Martlesham Heath, has been compiled, and compares well with the data published by the Meteorological Office. Such empirical tables, based on observation, are considered preferable to the assumption of a uniform lapse rate of $6\frac{1}{2}$° C. per kilometre, or to the use of any empirical formula. They are of interest in connection with a conversion table of barometric pressures into altitudes, published by the Fédération Aéronautique Internationale. The Meteorological Office have undertaken to prepare a similar table with a view to the recommendation of its adoption by the F.A.I. in place of that already existing and authorised, which has been calculated from an empirical formula.

An interesting method for the determination of cloud heights has been used by the meteorologist-in-charge at Farnborough. A searchlight was pointed vertically each evening for a period of two minutes, so that an observer with a nephoscope was enabled to obtain determinations of cloud heights on 27 per cent. of the evenings of observation. The method is an easy one, and might well be regularly employed at all aerodromes and meteorological stations where a searchlight is installed or where signal lights are used at night. With further reference to clouds some evidence has been advanced to suggest the occurrence of super-cooled clouds. The difficulty of distinguishing between ice-crystal and vapour clouds is known, and the result of laboratory or other experiments on this matter would be of interest.

Much work on the upper air has been done in the past by the aid of pilot balloons. Mr. J. S. Dines has collected in a single report descriptions of the many methods used in such observations, including some mention of the rangefinder method. The report, which has been communicated to the Committee and will be published shortly by the Meteorological Office, should prove of general interest to meteorologists.

Winds and Wind Structure.—More information on winds and wind structure has been accumulated in the past year. An anemogram record, taken at Quilty, County Clare, on the 27th January, 1920, shows the strongest gust (112 m.p.h., at 8.20 a.m.) on record at the Meteorological Office. The difference between the maximum as shown by the gust and the mean speed is of the same order of magnitude (60 m.p.h.) as is sometimes experienced with a line squall, but the rate of decrease of wind strength after the maximum was much greater. The rates of acceleration and deceleration of gusts appear to be a subject worth more attention by meteorologists. The amount of available data for the determination of these rates is scanty, as few anemometer records with an open time scale have yet been published.

Winds of 100 miles run in the hour have been reported from the Antarctic by Mawson, and in Seistan by MacMahon; they are surpassed by the winds of tropical hurricanes, but the recording anemometers have in such cases been almost invariably destroyed, leaving no record of the wind speed attained during the storm.

The calculation of the geostrophic wind, a fundamental and important basis for wind prediction, has been shown by the chairman to give good results in many cases if the prediction be made for short periods of time. For longer periods of twenty-four hours the accuracy in forecast is not good, and the improvement gained by an assumption that the wind has not changed during the period is not appreciable. It is hoped that further progress will be made in successful prediction, with increase in the knowledge of the wind at heights.

Turbulence and eddy motion have been considered in papers presented to the Committee by Mr. G. I. Taylor and Mr. Webb of the R.A.E. The former developed a theory of eddy dissipation which gave values for the rate of decay of the same order of magnitude as those deducible from the model airship experiments conducted with reference to the barrage at East Fortune. Mr. Webb has extended the mathematical analysis, and has co-ordinated the results of the wind channel experiments with the rate of decay of the South Wales tornado of October 27th, 1913. In connection with these papers diagrams showing an eddy at an early and at a late stage in its history have been constructed, the former relating to Holyhead for September 10th–11th, 1903, and the latter to Scilly for January 9th–10th, 1901.

The statistical representation of turbulence has been considered in a paper by Mr. G. I. Taylor, who suggests a method (1) for the specification of irregular curves such as a barograph record, and (2) for an analysis of the data that would give rise to diffusion in turbulent flow. The new method of correlation takes account of the slopes of the curves, whereas previous methods have employed only the values of the ordinates. Some calculations on the method have been commenced.

Instruments.—Several papers on instruments have been discussed by the Committee. A report by Mr. F. J. W. Whipple, of the Meteorological Office, on Robinson anemometers, has been prepared, and will shortly be published by the Advisory Committee. It contains an historical account of the progress made since the instrument was devised about 1843, and gives the factors for different sizes of the anemometer over a range of speeds. Further tests on the smaller instruments at very low speeds will shortly be made at the N.P.L., and at very high speeds in one of the wind channels at the R.A.E.; this will fill the gaps at present existing in our knowledge of the instrument. A large amount of useful work has been completed at the R.A.E. on the Robinson anemometer used as a small power unit on an aeroplane; this information will shortly be published.

The best method for the exposure of anemometers has been discussed, particularly with reference to the accessibility of the record to pilots prior to the commencement of a flight. The poles which carry the usual canvas wind-cones found on all aerodromes seem to provide a suitable position for their exposure if the recording portion of the instrument be placed in a convenient position near the main aeroplane hangars. On a similar question it may be noted that a satisfactory method of measurement of wind speeds over the ground has not yet been devised, and experiment on this point is needed.

Some forms of static pressure instrument have been tested at the R.A.E. One of the instruments, which is of the flat circular disc type with a double surface, having a single hole in each, gives results as satisfactory as the Nipher instrument, to which reference was made in last year's report. This so-called paddle instrument is not so liable to give erroneous readings in bad weather as the Nipher instrument, in which latter the openings of the gauze are small: the paddle instrument could be used on aeroplanes instead of a swivelling pressure head. It is hoped to perfect some instrument which will give the true static pressure in a wind, and various new designs are being experimented with. As an example of their use it may be noted that it is not possible to rely on the readings of any existing pressure-measuring instrument when the wind direction is unknown and of force greater than 3.

Meteorological Log.—Considerable attention has been given to the preparation of a form of meteorological log for the use of pilots. The form put forward for use requests information as to height, temperature, wind velocity and direction, visibility, cloud height, general weather conditions, and remarks on bumpiness or other peculiarities on special sections of the route. The forms will be filled in by the pilots themselves, who will post them direct to the Meteorological Office.

Aerial Navigation.—In connection with aerial navigation, Professor Bryan has communicated a paper suggesting the application of acoustic signals for route determination. He claims that if (1) aircraft can be provided with microphones capable of detecting terrestrial sound signals and if (2) suitable guns for producing such signals can be furnished, then it will be possible to introduce a satisfactory chain of stations for guiding aircraft in their journeys and localising aerodromes when aircraft are in their vicinity. There are many difficulties to be overcome in using acoustical methods for aerial navigation, and the matter is still receiving consideration. It is expected, however, that in the early future the institution of wireless stations on aerial routes and the perfection of the wireless telephone will provide adequate means for the guidance of aircraft.

To assist aerial navigation it has been suggested that kite balloons should be stationed at various points for taking and transmitting records of the wind velocity and direction, and of the temperature at heights. With kite balloons situated at suitable intervals on a long aerial route it would be possible to inform aircraft of the weather conditions they will meet, of the best routes for travelling, and of the most likely places for safe landings. Information acquired by this means would be of use for forecasting purposes.

Kite balloons provide perhaps the best means for determining wind velocities at heights. Other methods which are employed include the use of anti-aircraft shells, special firework shells, rockets, and sound ranging on pilot balloons fitted with an explosive charge. A novel method other than the above has been advanced, and consists in the design of a streamline balloon which will carry an explosive charge quickly to a given height, the charge being fired by some automatic means at the given predetermined altitude. The possibilities of self-recording theodolites for observing balloon ascents is also a matter which has received attention.

The Education of Pilots in Meteorology.—In addition to the above, the Sub-Committee have drawn attention to the importance of training aircraft pilots in meteorological work, particularly as affecting the important question of aerial navigation. They consider that the time has been reached when the better pilots may be expected to have some scientific knowledge in addition to their flying capabilities, with a view to their differentiation into two classes. The Air Ministry have already taken steps to give effect to the above recommendation, and service pilots will attend a course of theoretical instruction in physics and meteorology at the Royal College of Science, of practical navigation at Calshott, and of forecasting and the use of instruments at the Meteorological Office.

General Matters.—Diagrams of thunderstorm frequency for different parts of the world have been constructed and photographic reprints made. They show the highest frequency at Culebra in the summer months and in South Africa in the winter.

Some newly constructed maps of monthly rainfall for the globe in hemispheres (North and South) have been prepared by the Meteorological Office. The maps give at a glance the rain distribution which is responsible for the water supply to the world's river basins.

Observations on sandstorms have been supplied by the Deputy Director of Communications, Air Ministry, who has extracted the details from the reports of pilots on the meteorological conditions in the East. It is hoped that more information of this kind will be accumulated in the near future.

A communication giving details of all the aeroplane accidents attributable to weather conditions over a certain period has been received from the Air Ministry. From the list of accidents it would appear that almost all were directly caused by bad landings due to fog or fog and cloud, while apparently only a small number were due to wind. In a similar connection it is of interest to note that only one accident due to this cause has been recorded for the case of airships, although the latter, throughout the war, maintained their patrol services independent of fog.

FIRE PREVENTION ON AIRCRAFT.

Fire Prevention Sub-Committee.—The Fire Prevention Sub-Committee was appointed in response to a request made by the Air Ministry that consideration should be given to measures which might be taken to minimise the risk of fire on aircraft. During the war the fighting risks of aeroplanes were so great that no special attention was paid to fire prevention problems, which are of relatively greater importance for civilian aircraft. The Sub-Committee were able at a very early date to issue a preliminary report dealing with certain precautions which they considered would add appreciably to the safety of heavier-than-air machines, and might in some cases be introduced at once. Some of the precautions may be applicable to airships, but the report which has been communicated to manufacturers by the Air Ministry is not intended to deal specifically with this form of craft. The report refers more particularly to single-engine aeroplanes, similar precautions for multiple-engine aeroplanes being less easy of application.

Since the presentation of this report, the Sub-Committee have been able to investigate a number of special questions, and to recommend the conducting of certain experiments. In particular, one aeroplane has been modified so as to embody in its construction all the preventive measures against fire recommended by the Committee : this aeroplane will shortly be flown. The results of experiment are given in more detail below, and have been communicated in reports and papers to the Sub-Committee, which has held eight meetings since its appointment at the May meeting of the Advisory Committee.

Accidents Accompanied by Fire.—The first investigation undertaken by the Committee was to ascertain the causes and number of accidents to aeroplanes accompanied by fire. For existing data the Committee are much indebted to Mr. Cockburn, of the Accidents Department, Air Ministry, who has carefully collected and collated the information at his disposal. From the information provided by him two important conclusions were immediately deduced. In the first place it was seen that the fires occurring in the air which led to or were caused by accidents were comparatively rare, only five being recorded in a period of six months up to 31st December, 1918, during which over half a million hours were flown. During the next six months the corresponding figures were four and 36,000. Consequently the Committee are of opinion that the risk due to fire in the air is relatively small.

The other conclusion relates to the comparative immunity of rotary-engined aeroplanes from firing on crash, which, compared with fires in the air, is much more frequent and varies from a ratio of 1 in 35 crashes to 1 in 4·4 according to the type of machine. From these figures a striking difference between the rotary and stationary-engined types of aeroplanes was noted, the latter firing more than four times as often as the former. The inspection of a number of aeroplanes made clear the main difference between the two types, viz., that with the rotary engines, a bulkhead had nearly always been inserted between the engine and the rest of the aeroplane, a feature which was normally absent from the stationary-engined aeroplane. An interesting demonstration of the comparative safety of the rotary-engined aeroplanes was actually witnessed by the Committee while on a visit to the R.A.E. at Farnborough, when a rotary engine was started on the ground, flooded with petrol whilst running so that it caught on fire, and then as soon as the petrol supply was cut off the fire burnt out, leaving the aeroplane undamaged. In this aeroplane there was a metal bulkhead separating the engine from the rest of the aeroplane. This and other considerations led to the recommendation that engines should, wherever possible, be separated from the rest of the aeroplane, including the petrol and oil tanks, by a suitable fireproof bulkhead. In the case of airships it is understood that each car is a self-contained fireproof unit, a precaution similar in principle to that now recommended for aeroplanes.

Fire Tests on Magnetos.—Amongst the possible causes of ignition of an explosive mixture on an aeroplane, the magneto is certainly one. It consequently appeared important to the Sub-Committee to investigate whether magnetos are or can be made fireproof.

For immediate purposes the Committee have, as the result of experiment, recommended that the Air Ministry should permit the use of "approved" magnetos in the forthcoming competitions, the approved magnetos and their wiring to be so placed that they are not situated close to the carburetters or induction pipes, and are in such positions that they are thoroughly ventilated in flight. By "approved" magnetos are understood types which have not been known to cause fires on aeroplanes. Further, the Committee consider that on account of the great variability in fireproofness of individual magnetos of the same type it is not possible to state that any type of magneto in service is fireproof, although they are of opinion that future types could readily be designed so as to meet the now standardised fireproof test.

The standard method of test (R. & M. 186) adopted at the N.P.L. in 1914 has been altered to conform more nearly to the actual conditions possible in flight, the chief alteration consisting in the smaller amount of exhaustion of the experimental chamber and in the provision of a safety valve to prevent damage to certain parts of the magneto. The new form of test is now standardised for use at both the N.P.L. and the R.A.E., and a copy of this agreed standard form of fire test has been forwarded to the Director of Research.

The above standardisation is the result of many experiments made at the two establishments. An additional series of tests on magnetos in the presence of moisture has also been completed at the N.P.L. They showed that the magnetos would be safe in a damp condition when running on closed circuit. They would, however, be unsafe in a damp condition if

(1) one or more high tension leads became disconnected at the distributor;

(2) a high tension lead became disconnected at the plug and were not short circuited back to the magneto.

Ignition Cables.—In addition to the danger of ignition by sparking from a magneto, the breakage of ignition cables gives a possible cause of fire. The properties of ignition cables have therefore been discussed from the point of view of fire prevention. It is important that these cables should remain intact during service, and should not be liable to catch fire and burn. The metal sheathing which has been introduced to prevent interference effects with the wireless gear carried on many aeroplanes is not intended as a fire protection device. It is believed, however, that objections which have been raised to certain forms of high tension cable on account of evidence showing that the fracture of the conductor or braiding may give a spark, are now almost completely met by the provision of earthing connections every eighteen inches of their length. It is further desirable that the cables should be designed to have a low electrostatic capacity.

Backfiring of Engines.—Danger of fire in the air from ignition of an explosive mixture may also arise from the backfiring of the engine. A number of experiments to demonstrate this fact have been made at the R.A.E., and, while it has nearly always been found difficult to start a fire, there appears to be little doubt that backfiring of the engine is a possible fire risk.

The conclusions of the experiments can be summarised as follows :—

(*a*) Fire will not occur on any engine unless the conditions in proximity to the air intakes are suitable ; *i.e.*, unless petrol, petrol vapour, or other inflammable material is in such a position that it can be quickly ignited. (Wood, fabric, &c., is extremely difficult to set on fire in an aeroplane in flight, except when petrol is present.)

(*b*) Any engine may be caused to backfire by various breakages which may occur in flight. The conditions produced may be a necessary cause for a fire, but if the air intakes are carried well outside the cowling there should be very little probability of a fire starting inside the cowling of the machine. Leaks in the intakes are clearly not desirable for similar reasons.

Fire Extinguishers.—No less important than the prevention of ignition is the use, where possible, of a safe fuel, and the provision of suitable fire extinguishing devices. Experiments on the former have already been referred to in the section of the supplement dealing with internal combustion engines. Experiments on the latter are in hand at the R.A.E., attention being paid to the provision of a substance which will be suitable for fire extinction and will not freeze at low temperatures. Foamite, a patent fire extinguisher, offers many advantages over other substances for the extinction of fires in aircraft, and experiments with it have been made ; it is doubtful, however, whether its freezing point is sufficiently low for general use, and its slow action in spreading over solid surfaces leaves much to be desired.

The most successful fire extinguisher yet tried has a number of nozzles connected to a cylinder of carbon tetrachloride containing a capsule of carbon dioxide. The capsule provides the necessary pressure for forcing the liquid through the nozzles, as well as a quantity of inert gas in which combustion cannot take place. The whole apparatus as fitted to an aeroplane is comparatively light, an essential feature for adoption in such craft. It may also be noted that carbon tetrachloride has proved by comparison with other liquids to be, weight for weight, a good extinguisher.

Aeroplane Tanks.—It is evidently desirable that aeroplane tanks should not burst when an aeroplane crashes, as the spraying of the petrol over the machine increases greatly the fire risk. Some promising experiments on this question have already been carried out by the Director of Research, showing that certain composition tanks possess the property of collapsing when they are dropped from a considerable height without permitting the escape of petrol as a fine spray. Existing experience points to the fact that the seams of the tanks are the first portions to give way if the blow to which the tank is subjected is not too severe, but in many cases tanks have been thrown clear and uninjured when an aeroplane has crashed. Further experiments on the question are in hand, and it is hoped to discover what are the best qualities for a crash-proof tank.

Spontaneous Combustion of Materials.—In addition to the above questions it has been considered advisable to investigate what possibilities there may be of spontaneous combustion of materials in warmer climates than that of the British Isles. A case has been reported where some padding composed of red leather tightly stuffed with cotton, and attached to the centre section of an aeroplane, caught fire during a flight in India. The possibility of the spontaneous ignition of materials made of celluloid, cotton, kapok, and other similar constituents when soaked with oil, &c., is being considered; it is hoped that as the result of experiments more information on the matter will soon be available.

LOAD FACTORS FOR HEAVIER-THAN-AIR CRAFT.

Load Factor Sub-Committee.—The Load Factor Sub-Committee was formed in October, 1919, in accordance with a desire expressed by the Secretary of the Air Ministry, following a communication received by the Air Council from the Society of British Aircraft Constructors, in which the question of load factors for commercial aeroplanes was raised. The Committee was composed of representatives from the Air Council, the Royal Aeronautical Society, the Society of British Aircraft Constructors, and the Advisory Committee for Aeronautics, and was given the following terms of reference:—

> "To consider and report as to the definite rules which should be adopted to govern the load factors required for all classes of civil aircraft, and upon which certificates of airworthiness may be based."

The Sub-Committee have held four meetings, at which the question of load factors for heavier-than-air craft has been very fully discussed, and they have unanimously approved a report which was communicated to the Air Ministry in January last. At their meetings they have discussed 19 papers, the conclusions of which are, in the main, embodied in their report. For these papers the Committee have to thank, in addition to their own members, Mr. A. J. Sutton Pippard, who contributed the many valuable results of his calculations, Mr. Douglas, of the Royal Aircraft Establishment, and also Major F. M. Green, for a paper on the load factors for undercarriages. Mr. A. J. Sutton Pippard later became a member of the Sub-Committee, on the resignation of Lieut.-Col. Mervyn O'Gorman.

Classification of Aeroplanes.—In preparing a schedule of load factors it was found imperative to divide civil aircraft into two classes. The "general" class, which included all aeroplanes not in the "commercial" class, had their strength specified by the consideration that the aeroplanes should be strong enough to permit of stunt flying. In the other, the "commercial," class, the specified load factors were lower, as the craft in this class include only those used for strictly commercial work involving straight flying, stunting of any kind being prohibited. The schedule was given in tabular form under these two heads.

Nature of the Specifications.—In the Sub-Committee's report, details are given of the methods of specification for the load factors, and to this reference should be made. The schedule was composed in all of six specifications for each class of heavier-than-air craft; the load factors with the centre of pressure of the wings in its most forward position and in the position corresponding to maximum horizontal speed at ground level, together with a factor of safety in a terminal nose dive, specify sufficiently the strength of the wings, fuselage, and tailplane for most attitudes of flight; a specified lift coefficient for the fins and rudders determines the strength of these parts and also of the lateral loading of the fuselage; and a static load factor, with a specified vertical velocity for determining the travel, determines the strength of the undercarriage. In the Commercial class aircraft which are longitudinally stable over the whole flying range are allowed a reduction on the figure giving the specified load factor.

For the calculation of the strengths of aeroplanes to meet the above requirements, some special matters have to be noted, and these are referred to in the report. In checking the calculations made by manufacturers, the methods given in the Ministry's revised Handbook of Strength Calculations (H.B.806) will be employed.

Magnitude of the Specified Load Factors.—The magnitude of the specified load factors has been fixed by the consideration of the known stresses occurring in aeroplanes as exemplified by the experience of the Air Ministry during the war, especially with regard to accidents due to breakage of parts and also by the results obtained in accelerometer records. In the commercial class the load factors vary from 6 to 4, according to the weight of the machine, the figures for the general class being higher, with a maximum of 8 for the smallest craft. The factors of safety (1·75) in a terminal nose dive are the same for the two classes; so also is the specified vertical velocity (10 ft/sec.) for determining the travel of the undercarriage. The specified figures for the lift coefficient on the fins are 0·6 for the general and 0·5 for the commercial class respectively.

Future Work of the Sub-Committee.—In drafting a schedule of load factors the Sub-Committee have realised that although the specifications laid down by them are sufficient to meet the needs of the moment, it will doubtless be necessary to revise the schedule from time to time in accordance with the demands arising from improvements in constructional methods and in design. It is clear that commercial considerations will tend where possible to lower the load factor in order that greater loads can be carried; in this connection reference may be made to a paper by Mr. Pippard on the effect of the variation in load factor upon the structural design and performance of an aeroplane. This paper has been published by the Advisory Committee for Aeronautics.

Other distinctions involving the division of heavier-than-air craft into more than two classes will possibly have to be made; also special consideration may be necessary of the design of different forms of undercarriage, which should be slightly less strong than the rest of the craft. In addition, it may be found expedient to adopt an entirely different method of specification by grading the load factors, not on a weight, but on a weight per horse-power basis. In this last connection, Mr. Pippard's paper on the aeroplane of consistent strength, published in *Engineering*, 30th January, 1920, is of special interest.

Yet another question is the limitation of the pilot's power to injure an aeroplane in flight by so designing the controls that too large a stress cannot be put on any portion of the craft.

FABRICS AND DOPES.

The study of the deterioration of textiles in use has been continued and extended. The loss in strength which is found to occur when unprotected fabrics are exposed in the open, as in aeroplanes, airships, tents, &c., has been found to be due to three main causes, any of which may be the predominating factor in special cases. The presence of acidity, derived from defective treatment in manufacture, from excessive atmospheric pollution, from oxidation of sulphur present in the proofing in airship fabrics, or from decomposition of certain ingredients which were formerly used in dopes, has long been recognised as a possible explanation of deterioration. Roughly quantitative data have now been obtained as to the relation between concentration of acid and rate of deterioration, and it has been shown that quite simple tests are capable of detecting the minimum amount of acid which will cause noticeable weakening on exposure. The action of light has been examined in greater detail, both by laboratory exposures to ultra-violet light and by the weathering of fabric in tropical countries. The previous conclusion that light of wavelengths shorter than those of the visible spectrum was mainly concerned in the deterioration has been amply confirmed, and means have been found for preventing it in most cases. A third agency has now been shown to be operative in very humid climates, viz., the development of moulds and bacteria, which may, even in the tropics and with freely exposed fabrics, outweigh in effect the destructive action of light.

The physico-chemical examination of solutions of cellulose acetate in various mixed solvents has revealed curious differences between different dope diluents in their action on the viscosity of acetone solution: practical results of some importance may be expected from an extension of these tests. The question of the inflammability of doped wings has been examined from several standpoints: nitrate and acetate dopes differ considerably in their resistance to ignition and in rate of propagation of the flame, and varnishes may alter these resistances considerably. It appears, however, that no doped wing is likely to burn in the air except when it is fairly saturated with oil or petrol.

Dope Solvent Recovery.—Experiments have been carried out at the R.A.E. with the object of devising a practicable method for recovering the volatile solvents which are lost in the drying process when dope is applied in the usual manner. An experimental plant has been erected consisting of doping chambers and recovery system, and a series of large scale tests has been carried out. It has been found possible to recover readily 60 per cent. of the solvents. An estimate is being made of the cost of working a recovery plant on a scale suitable for a small aircraft factory on a peace establishment.

Research has also been continued at the R.A.E. on the development and improvement of aeroplane dopes, particularly pigmented dopes. A systematic study of new solvents and softeners has been carried out and new esters of cellulose have been prepared and examined as to their suitability for dopes.

Experiments have been carried out to determine the relationship between the amount and nature of dope coverings and the protection against deterioration by light afforded to the fabric.

Further experiments on the permeability of rubbered balloon fabrics have led to the suggestion that the physical structure of the rubber layer is of paramount importance in fixing the leakage of a well-proofed fabric, and a working hypothesis has been put forward pointing to experiments that may lead to the elucidation of the complex relations which have been found.

LIGHT ALLOYS AND OTHER MATERIALS FOR AIRCRAFT CONSTRUCTION.

Systematic progress has been made with the study of light alloys for aircraft purposes. The development which took place during the war, although guided as far as circumstances would permit by scientific investigation, was none the less so rapid and carried out under such difficulties in regard to materials, that much of it remains without a secure foundation of systematic knowledge. The work during the past year has been directed to following up and examining more closely promising results already achieved and to the detailed investigation of series of alloys in the directions suggested by previous experience.

The more fundamental work has been the study of the constitution of various groups of ternary alloys of aluminium. The study of the systems aluminium-zinc-copper, aluminium-magnesium-silicon, aluminium-iron-silicon is approaching completion, but the important system aluminium-copper-nickel has proved to be extremely complicated and much further investigation is required. The systems aluminium-copper-magnesium and aluminium-nickel-magnesium also need to be carefully examined.

Good progress has been made in regard to the treatment of special alloys, both for casting and working, which have been developed at the National Physical Laboratory, including the study of heat treatment and of the influence of methods of melting, gases, &c., and also questions of working and annealing in regard particularly to their effects on the properties of the alloys and on their permanence under stress.

At the R.A.E. a number of special questions have been investigated. Materials complying with Air Board specifications L5, L8 and L11 have been exposed for varying periods at temperatures ranging from 200 to 450°C. in order to investigate their tensile properties after exposure. None of the alloys was found to lose in ultimate stress value and all gave slightly higher ductility values after treatment.

The influence of mass on the mechanical properties of nickel chromium steels after heat treatment has been examined. It was found that bars of greater section than $1\frac{1}{4}$ in. diameter could not be hardened to the core ; bars $2\frac{1}{2}$ in. diameter hardened only to a depth of $\frac{1}{2}$ in., the core being unchanged.

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The relationship of coarse macrostructures to mechanical properties in crankshaft steels has been studied. Ultimate stress values do not vary, but ductility and notched bar values are greatly influenced by the fibre of the material. When the fibre is parallel to the axis of test pieces higher values are obtained than when the fibre lies at right angles to the axis. The slag content of the steel and the grain size are important factors.

Steel strip for metal wings and spars has been investigated. Tests have been carried out to show the mechanical properties of several types of steel cold rolled into strip, in various conditions. The influence of zinc coating on the strips has also been investigated. The results so far obtained indicate that a satisfactory zinc coated material can be produced for this purpose.

The influence of pickling on steel sheets is under investigation. It has been found that pickling causes brittleness, and work is in hand on prevention and also methods of removing the brittleness.

Corrosion tests have been continued on steel and light alloys coated by means of paint and varnish as preventives against corrosion and a series of contact tests are under observation.

A considerable amount of general research on timbers has been carried out, and variation in the mechanical strength and properties of spruce, mahogany, ash and walnut has been investigated for varying degrees of moisture content and for various angularity of grain. The rate of absorption of moisture by 1 in. cubes and the resulting increase of dimensions have been measured for the same four timbers.

A report dealing with the various properties of timber as they affect aircraft construction has been prepared and issued.

SEAPLANES.

During the last few years the seaplane has steadily increased in size, as is shown by the fact that the displacements of models sent to the tank for test have increased from 6,000 to 80,000 lbs. per machine in a period of three years, with corresponding increase in size of float. Some tests were made in 1916 on loading up hulls of varying beam, and owing to the importance of the subject a more exhaustive set of experiments has been made this year on a model representing a much larger machine, similar in type to the P.5. These experiments show the effect of (1) loading up a float of given beam, and (2) of increasing the beam, keeping the length the same for a given load. They also showed that the seaworthiness could be improved by a moderate upward tilt at the fore end, but only at the expense of resistance at low speeds.

(*a*) These tests led to a further investigation to measure separately the water lift and resistance on the two parts of the hull, forward and aft of the main step, showing that by far the major portion of the total resistance is contributed by the forebody. It is proposed to complete this investigation by carrying out similar tests on a model flying boat built up of straight frames, sides, and floor similar to the F type of machine.

(*b*) The model impact tests carried out in 1918 have been followed up by full-scale tests on an F boat, but these were not completed owing to damage of the machine. Arrangements are now in hand to finish the work. So far the tests show that in comparatively smooth water the pressures met with in ordinary landing and taxi work seldom exceed about 4 lbs. per sq. in., and these forces are quite local.

(*c*) A complete set of experiments has been made on a model of the Felixstowe Fury for the Accidents Investigation Committee The object was to determine the effect of varying the load on the hull upon the moment necessary for its longitudinal control at a series of speeds, and to note any diving tendencies at high speeds. The hull can be trimmed through a very fair angle range without excessive control moment. It was found that, if the machine settles on the water with considerable forward trim, it is liable to bury its fore end under water.

(*d*) Some test work has been carried out on amphibian machines and flying machines having hulls fitted with rear skid and wheels which can be lowered into position if it is desired to land on the ground. The presence of the wheels and supporting struts on the models sent for tests had the effect of considerably increasing the hump resistance and the tendency to nose under at low speeds. By alteration of form and position of wheels, &c., this type has been rendered stable in running, and the resistance due to wheels, &c., reduced within practical limits. The subject merits further experimental investigation if the type is one for which there is any demand.

(*e*) The full scale P.5 tests so far made indicate that this machine, like the C.E.1, is free from all tendency to porpoise. Recent work on this subject shows that it is often possible to attain non-porpoising conditions with comparatively unimportant changes in hull shape, and without imposing any compensating defect.

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